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A Stream Survey of Riley Creek, Coles County, Illinois, Using Macroinvertebrates as Indicators of Organic Pollution

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A Stream Survey of Riley Creek Coles County, Illinois Using Macroinvertebrates as Indicators of Organic Pollution

(TITLE)

BY

Joseph R. Rowe

THESIS

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF

Master of Science in Zoology

IN THE GRADUATE SCHOOL, EASTERN ILLINOIS UNIVERSITY
CHARLESTON, ILLINOIS

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I HEREBY RECOMMEND THIS THESIS BE ACCEPTED AS FULFILLING
THIS PART OF THE GRADUATE DEGREE CITED ABOVE

16 May 77
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DEPARTMENT HEAD

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ABSTRACT

A stream survey of Riley Creek in Coles County Illinois, was undertaken to determine ecological trends and the qualitative status of the aquatic community throughout the course of the stream.

The survey encompassed the entire length of Riley Creek from the area of its status as an intermittant waterway to its confluence with Cassel Creek. Sampling periods included the months of April, May, June, July, October and November.

Macroinvertebrate collections were made at six locations along the stream approximately equidistant from each other. The organisms were assigned tolerance levels as designated by the Illinois Environmental Protection Agency.

Physical and chemical parameters that were tested for included Temperature, Turbidity, Nitrates, Nitrites, Ortho Phosphates, Dissolved Oxygen, Biological Oxygen Demand, Hydrogen Ion Concentration and Total Hardness.

The taxa and tolerance level of the macroinvertebrates was correlated with the physical-chemical parameters tested for to obtain a general stream classification at each smapling site. It was determined, through these data and guidelines set down by the Illinois E.P.A., that Riley Creek is generally in an unbalanced condition. This fact is further exemplified by point sources of pollution among the sampling sites.

LITERATURE REVIEW

A definitive stream survey using macroinvertebrates as indicators of pollution, requires an understanding of how physical-chemical parameters affect a stream ecosystem. Knowledge of the interrelationships between the macroinvertebrate community and their environment is also necessary.

The categorizing of macroinvertebrates into tolerance groups, may allow the areas of stress in the stream to be defined as to limiting factors. Such tolerance groups are specifically associated with almost every taxa. In this type of investigation the watershed types surrounding each sampling site as well as substrate content within each sampling site, must be studied. The fact that different watersheds produce many different substrates for which specific taxa of macroinvertebrates have a preference requires extensive investigation. Any effluent to the stream that might possibly be a point source of pollution must also be correlated with natural physical variations and fluctuations in the populations of the macroinvertebrate community.

1. EARLY INVESTIGATIONS OF MACROINVERTEBRATE COMMUNITIES

The earliest and most significant study of macroinvertebrate communities was the study of the middle Illinois River, (R.E. Richardson, 1913). This study was expanded over a twelve year period with investigations into distribution, abundance, valuation and index values of members of the macroinvertebrate community. The only chemical parameter measured was dissolved oxygen. Species were classified into seven categories with reference to distribution and apparent tolerance to pollution. The categories were:

I. The pollutional group, including two genera of Tubificidae, which reached their highest numbers during the period of the greatest pollution.

II. The sub-pollutional group, (usually tolerant), including Sphaeriidae, Bryozoa, Hirudinea and Chironomidae larvae.

III. The sub-pollutional group, (usually tolerant or doubtful), which includes primarily miscellaneous Chironomidae larvae.

IV. The sub-pollutional group, (less tolerant). A conglomeration of twenty species of Chironomidae, Sphaeriidae, Gastropoda, Oligochaeta and Hirudinea.

V. Pulmonate snails and air breathing insects. These are normally surface and edge forms which have a preference for clean water thus lacking an index value in connection study.

VI. Current-loving species, (other than pulmonate snails and air breathing insects). These normally have a preference for clean water, but can endure the waters of the sub-pollutional zone in cases where there is unusual current

These include Pleuroceridae, Isopoda, Porifera, Bryozoa and Hydropsychidae.

VII. Clean-water species, including thirty species in all, each in limited numbers. The following groups are represented: Crustacea, Bryozoa, Unionidae, Valvatidae, Amnicolidae, Viviparidae, Odonata, Chironomidae, Trichoptera and Coleoptera.

This list was sub-divided into "less sensitive" and "more sensitive" categories in a later study, (Richardson, 1923). The study area extended from La Salle, 101 miles below Lake Michigan, to Grafton, at the mouth of the Illinois River. Pollution was characterized as the effluent entering the river primarily from the Chicago Sanitary District, a flow which began in 1914. The effect was the greatest in the upper river and slowly diminished downstream. Efforts by Richardson to select index species whose abundance would mark grades of pollution in which such a species predominates was difficult. The divisions established for such species were indistinct creating difficulties in drawing such boundaries as where zones intermingled at a given locality. The study showed the effect of pollution increased as numbers and diversity of species decreased. The effects were most drastic at sampling sites closest to the pollution. In a later study, Richardson (1923) correlated the data with the 1913 study in which portions of the river were not receiving sewage. These were used as control areas so that the downstream progress of the pollution could be observed over an extended sampling period. In the 1923 survey the river was divided into three zones:

I. The central channel zone

II. 100 feet of the central channel zone on each side

III. The outer zone, the area beyond the 100 ft. zone to the line at bank which was the height of the water level during normal rainfall in the summer.

Species were subdivided into three groups on the basis of apparent degree of tolerance.

I. Pollutional or more or less tolerant species, including tubificid worms, leeches, midge larvae, sphaeriidae, Musculium and Pisidium.

II. Cleaner preference species, including primarily current-loving species of Gastropoda, Bryozoa, Crustacea and Insecta usually occuring near shore.

III. Missing members of the original bottom fauna, including Gastropoda of the families Viviparidae and Amnicolidae, and Insecta nymphs and larvae of the orders Ephemeroptera, Odonata, Hemiptera, Neuroptera and Coleoptera.

The term "pollutional" used in both studies corresponds with "mesosaprobic" as used by Forbes and Richardson (1917) in their early studies of the Illinois River. The term "tolerant" was not quantitatively investigated because the degrees of disruption. This provides consideration of the wide range of certain organisms which are not limited to specific zones such as between polluted and clean water. Data in the 1923 study shows a majority of the organisms occur in group III, those expected but not occurring in their natural areas. The greatest damage since the 1913 study had occurred at the sampling site above Havana where the flow is slowest, and sedimentation is greatest, especially following floods.

II. EFFECTS OF VARIOUS SUBSTRATES

And Habitat Preferences

Leudtke and Brusven, (1976), used driftnets, basket samplers and artificial streams to evaluate the impact of sand sedimentation on stream insects. Insect drift is a major means of colonizing natural and altered streams (Waters, 1964). Results indicated downstream movement out of sandy substrate areas by drifting insects and (poor swimmers). Samples taken in sandy substrates showed colonization most frequently occured by insects that are common to the substrate, such as chironomids, or strong swimmers such as baetids and ephemerellids. The weaker swimmers and non-burrowing organisms merely drifted past the sandy substrate to more favorable areas. Results also showed that most common riffle insects were unable to move upstream over sandy substrates and the combination of exposure to current and the instability of the sand is responsible for restricting such movements. A study of bottom fauna-substrate relationships was conducted by J.V. Ward (1945-1974), to determine changes in the stream environment and community structure of macroinvertebrates. The stream remained clear and unpolluted between the two sampling dates. A neutral pH was also maintained. Natural changes in watershed, flow, temperature and vegetation occurred, however, macroinvertebrate composition remained essentially the same. Minor variations that did occur were attributed to alteration of emergence time due to temperature difference and breakdown of bedrock areas. Egglishaw, (1964), took monthly samples from the bed of a stream riffle which demonstrates that the distribution of bottom fauna in the riffle significantly correlated with the distribution of plant detritus. The distribution of certain species of Ephemeroptera, Plecoptera and Chironomidae were closely correlated to amounts of plant detritus in the riffle area.

The distribution and species of Simuliidae and Hydroptilidae were shown not to be correlated to the amount of plant detritus. Dodds and Hisaw, (1925), investigated the peculiarities of structure and habit which enable caddisflies to occupy a wide variety of habitats from stagnant pools, to the swiftest mountain streams. Their results showed that the case, not the body form, allowed the caddisflies to fit the varied habitats. Also substrate particle size, form, and composition occurred in a direct relationship to the strength of the current. They showed caddisflies and mayfly nymphs occupied a wide range of the habitats, and suggested that with a flattened body form, these animals developed an adaptation for life upon rocks exposed to strong currents. The species with round body forms were found to have developed a clinging ability that allows them to occupy essentially the same habitat. Rosine, (1950), reported on the distribution of invertebrates on submerged aquatic plant surfaces in Muskee Lake, Colorado. Plant material, living or dead, creates new habitats for a variety of aquatic invertebrates. The surface area provided by aquatic plants may be as important as the food and oxygen they supply for the invertebrate community. Results showed that there is great variation, even to the extent that certain invertebrate groups utilize specific plant stypes. Seasonal fluctuations in numbers of invertebrates were shown to be affected by the annual life and death cycle of aquatic plants. Linduska, (1938), determined differences in species composition of mayfly nymphs over a specific section of trout stream in Montana. Conditions were associated with known differences in relative numbers of nymphs of certain species. Results showed that several of the species occurred in well defined types of stream substrate, whereas, others were restricted to very particular substrate types. Flow was shown to be of little consequence and species indicative of substrate type could be found regardless of how turbulent the flow proved to be.

Stream flow, however, did appear to affect the vertical distribution of nymphs depending upon their ability to navigate currents.

III. METHODS USED FOR THE EVALUATION OF STREAM COMMUNITIES

Cairns and Dickson, (1971), designed a system to enable personnel concerned with water quality monitoring to use bottom fauna organisms to evaluate the effects of waste discharges. The authors stressed the fact that aquatic organisms have different life cycles and different sensitivities to various types of stress. Those differences can be used to assess the history of the pollution and its effects on a given area. The authors discussed how to design a pollution survey with well defined objectives and also, how to determine where to sample. Different devices were used in quantitative samples and were discussed with the pros and cons of each given. The authors also went through several types of diversity indices. And, discussed chemical substances which affect the quality of water, the variation of water quality with their mechanisms acting within a great range of parameters to lower water quality. Attempts to set up standards that were meaningful in terms of toxicity towards aquatic organisms were difficult due to the large numbers of toxic compounds and vast numbers of species with varying tolerance levels. The author established water quality criteria by evaluating biological conditions in receiving streams. Results showed that most effluents produce striking differences in the structure of the benthic community. A series of populations were identified in a polluted stream until the water quality and biotic community approached a normal situation. The structure of the biotic community was placed in a diversity index derived from the information theory and yielding values which are designated as follows: 1 is a site of heavy pollution, 2 and 3 are areas of moderate pollution and values exceeding 3 are areas of clean water.

Shelford and Eddy, (1929), based the methods of their study on a set of hypotheses to be proven. The hypotheses were that stream communities exist and undergo successional development and reach and maintain a quasi-stable condition. The aquatic community also goes through seasonal and annual differences as do terrestrial and marine communities. The authors characterize two general types of permanent stream communities:

(a) Those found in swift water of a stable hard bottom,

(b) Those characterizing slower moving water or pools with soft unstable bottoms.

Invertebrate indicator organisms were placed in two classes, one of which indicated temporary flood conditions and secondly, those which indicated average or permanent conditions. The indicators which fluctuated in the current were sampled with quantitative devices, nets and the No. 30 U.S. standard seive, along with qualitative observations of changes in the benthic community. Artificial streams were also compared with natural communities. Results showed that permanent stream communities undergo successional development, reach and maintain a quasi-stable condition and manifest seasonal and annual differences. The authors suggest three methods for stream community analysis.

(a) Experimental quantitative study to determine the community history by eliminating all organisms or introduce artifical substrates to allow natural progression of the new communities to take place.

(b) Study the ultimate in stream development by taking advantage of comparisons through dams, canals and waters maintained as a stable natural stream not subject to fluctuations.

(c) Quantitative studies of communities in natural environments compared with quasi-experimental communities. Observations should be made to determine dominance or species control over the existing community.

IV. REFERENCE STUDIES ON STREAM COMMUNITIES AND MACROINVERTEBRATES AS INDICATORS OF POLLUTION

Hynes, (1974), in his study on the significance of macroinvertebrate in the study of mild river pollution, worked through a system of cause and effect. The point that was stressed in this particular paper was that studies in the aquatic environment should be directed toward the area of deterioration. Pollution was described as a word with no absolute meaning and there is now no type of pollution, domestic, industrial and agricultural that doesn't have an effect on the flow and fauna of the aquatic ecosystem. The advantages of using macroinvertebrates as indicators was discussed comparing it to fish and plankton. It was also stated that changes in natural physical parameters such as water hardness, silt deposition and oxygen only induce slight faunistic changes and effect only relative abundance. The author also noted that there is a need to present biological data by statistical methods which can be understood and analyzed by engineers but the difficulty exists in the fact that biological results cannot always be expressed by mathematical formules and furthermore, a reasonable judgment of biological effects is often needed. Nilson and Larimore, (1966), studied the development of invertebrate communities on long substrates in three habitats: Slow moving shallow water, riffle areas and pools. The orders of organisms varied for each habitat and substrate. Communities on artifical substrates did not reach a climax stage because organisms, detritus and silt were constantly being accumulated and sloughed off. Fluctuations of populations of macroinvertebrates on the substrates also occurred with changes in physical conditions of the habitats seasonally.

Benthos and plankton studies were conducted by Anderson and Weber, (1965), at three sampling sites, two on the Ohio River and one below the Confluence of the Kanawha River. Comparisons of benthos, plankton and physical parameters are described. The populations at the three stations were distinctly different with respect to occurrence and abundance of genera and species of benthos and plankton. These differences are used to estimate levels of enrichment and detect influences of toxic materials. Physical and chemical data supplement the biological data and are used to characterize conditions at the sites and used as a comparison for following studies.

Gaufin, (1952), conducted a year-round study on the effects of pollution on a midwestern stream with the U.S. Public Health Service on the Mad River, Ohio. The study determined how waste discharges to the stream affected the physical-chemical environment and macroinvertebrate communities coinciding with seasonal changes. Data on species composition, abundance, and adaptations of the macroinvertebrates collected were associated with the physical-chemical tests. The organisms were placed in three categories. The categories were based on their tolerance to organic enrichment and their preference as to clean water. Nearly fifty percent of the organisms found were pollution-preferring forms. An invertebrate and organic pollution study was conducted for one year on Lytle Creek, Ohio, by Gaufin and Tarzwell, (1956). Composition of stream communities were associated with organic wastes from Wilmington, Ohio. The pollutant was primarily sewage and the physical-chemical characteristics of the effluent were related to the quantitative and qualitative composition of aquatic populations in each zone sampled.

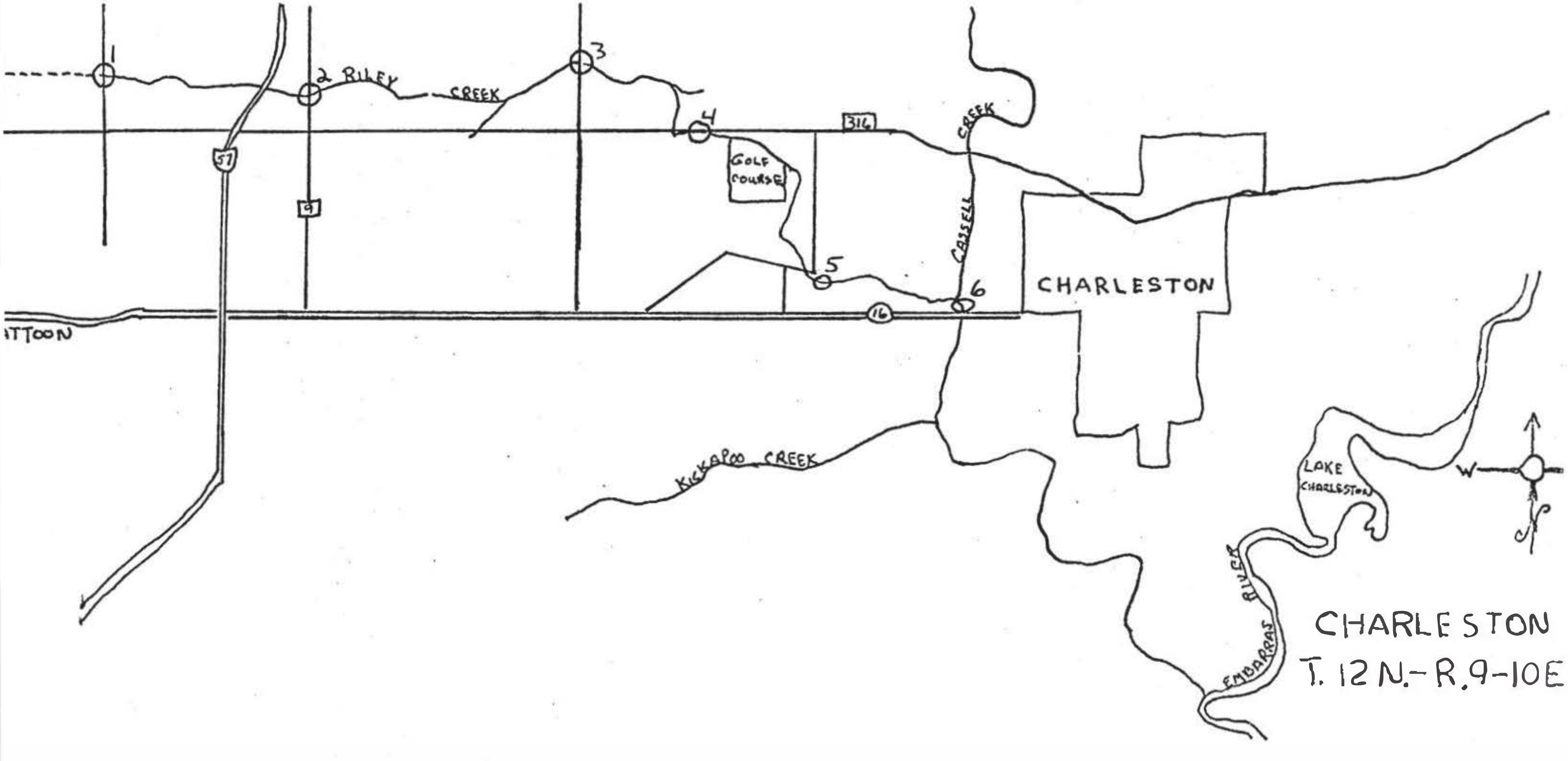
Seasonal and diurnal fluctuations in dissolved oxygen and pH were greatest in late spring and early summer. As was expected, the benthic communities had the greatest diversity above the effluent. The site just below the outfall had only species adapted to life under conditions of low D.O. and gradually downstream through the zone of recovery their diversity increased to a point where the effects of the polluting organics was minimal, and the communities maintained a natural balance. A study of the benthic macroinvertebrate community structure in a Great Plains stream receiving feedlot runoff was conducted by Prophet and Edwards, (1973), to determine the effect of feedlot runoff on the Cottonwood River in Kansas. The runoff was evaluated by analysis of the macroinvertebrate communities. Sixty-five taxa were identified during the study. The species diversity significantly increased in the runoff area after the feedlots were closed. The species diversity below the area of feedlot runoff was considerably lower than at other sites. The data indicated adverse effects by the periodic feedlot runoff and continuing adverse effects on the aquatic communities. Recovery was rapid after the feedlots were shut down and the organic load in the river was reduced. Diptera are represented by forms which may be found in all types of stream habitats from the cleanest to the most polluted. Diptera as an indicator of pollution was studied in Lytle Creek in Ohio by Paine and Gaufin (1956). Ten families of diptera were collected, Psychodidae, Dixidae and Ephydride were very rate and occurance was negligable, however, Culicidae, Chironomidae, Heleidae, Simuliidae, Stratiomyidae and Tabanidae were taken frequently. A total of 94 species were found and separated into three categories:

(a) Pollutional
(b) Facultative or tolerant
(c) Clean water forms

Species with special adaptations for obtaining oxygen from the water surface remained unaffected by low dissolved oxygen levels. Chironomids were found to be adaptable to many stream habitats and because of their selectivity of habitat were considered the most important group of indicator organisms. The authors also discussed species separated as to their substrate and zone of pollution preferences. The aim of the study, by Morgan and Eggleshaw (1953), was to determine the composition of the bottom fauna and the distribution of the different species, and to relate these findings to physical and chemical conditions of the stream and the geology of the watershed of streams in Scotland. The authors compared spring and summer fauna and results showed a three-fold increase in number of invertebrates in summer and their numbers were the greatest in the summer. The authors discussed the preference of each species found in the fifty streams investigated as to substrate and the effects of mild (household) pollution. Most groups of aquatic organisms have been suggested as valuable indicator organisms, however, none are adequate alone, according to Goodnight (1973). In this study, the entire community was considered as a unit of study in determining stream conditions. The author discussed the value of living organisms for pollution studies, separating them into three groups: fish, micro-organisms and macro-invertebrates. He considered particular orders and groups of macro-invertebrates and explains why they are particularly good indicators or why they are not.

The amount of enrichment or pollution is compared with each group, in amounts they can tolerate. The purpose of a study by Gaufin and Tarzwell, (1952), was to devise procurements and equipment for stream surveys and also to determine effects of diurnal, seasonal and physical-chemical conditions. The sampling was qualitative and quantitative and the levels of BOD and values assigned to fish were also investigated. The stream surveyed was Lytle Creek in Ohio. The authors discussed the species that were found and their substrate preferences, contrasted by physical-chemical data and the possible effects of such data on invertebrates. Results showed that single species of organisms such as Tubifex or Chironomis tentans, cannot safely be used as indicators of pollution unless their relative abundance is considered. The absence of formerly existing intolerant or clean water forms was an important index in evaluating the degree of pollution. Pollutional zones were inhabited by species few in number, but great in numbers of individuals. All enviromental factors were taken into consideration when interpreting the distribution of organisms as an index to pollutional conditions.

RILEY CREEK SAMPLING SITES



INTRODUCTION

This survey documents stream quality conditions throughout the course of Riley Creek, based on the physical-chemical parameters investigated and the macroinvertebrate communities present. Aquatic macroinvertebrates are classified as organisms which can be seen with the naked eye and will not pass through a No. 30 U.S. standard sieve. Nearly all aquatic animals are sensitive to physical-chemical changes in their natural environment, thus the determination of the biological components of the stream are important in judging its quality. Questions often arise during such an investigation, such as exactly what characterizes "clean water" in a stream in an area of intensive agriculture whose source is primarily field runoff and sub-soil seepage. Another concern is with the varying types of substrate at each sampling site throughout the course of the stream. Is there a characteristic community structure of macroinvertebrates, or will the communities fluctuate greatly with the influence of pollutants and seasonal effects of temperature and low water? Answering these questions is difficult, but more important than definite answers is a clear view of the study of a stream community and determining exactly what is present and the manner in which it changes. Generally, under natural conditions, a stream with a constant flow will support a great diversity of species but with relatively few numbers of individuals due to predation, competition for space and a limited food supply. The limited mobility of macroinvertebrates and their sensitivity to pollution makes them ideal subjects for study under natural and stressed conditions.

With the demand for potable water increasing constantly as illustrated by the midwest drought of 1976-1977, there is a necessity for monitoring all of our waterways no matter how small so that water of high quality can be maintained to its point of use.

MATERIALS AND METHODS

Macroinvertebrate collections were made during the months of April, May, June, July, October and November of 1976. Qualitative samples were obtained by hand picking from substrates submerged or partially submerged in the stream and the use of the No. 30 U.S. standard sieve. Time expenditure per station was based on the law of dimishing returns otherwise approximately 40 minutes sampling time was used. Efforts were made to collect from all habitats in the area at each sampling site until further sampling failed to provide additional taxa. Sampling sites were located approximately equidistant from each other along the stream so that changes in physical-chemical and biological parameters could be monitored for the stream as a whole. Special consideration was taken to locate any point sources of pollution in areas among the six sites. Field notes were taken at each sampling site at each period to note conditions and changes that had taken place between sampling trips. Organisms were preserved in 70% ethanol. After identification, the organisms were assigned a tolerance status according to the Environmental Protection Agency Criteria for Stream Surveys, (1975). The four tolerance status categories for aquatic macroinvertebrates found in Illinois are defined by the E.P.A. as:

> INTOLERANT: Organisms whose life cycle is dependent on a narrow range of ideal environmental conditions with respect to dissolved oxygen, biological oxygen demand and hydrogen ion concentration Intolerant organisms are rarely found in areas of organic enrichment and are replaced by more tolerant species upon degradation of their environment.

MODERATE: Organisms which lack the extreme sensitivity to environmental stress shown by intolerant species but cannot adapt to severe environmental degradation. Moderate organisms usually increase in abundance with a slight increase in organic levels.

FACULTATIVE: Organisms which display the ability to survive over a wider range of environmental stresses and show a greater degree of tolerance than either Intolerant or Moderate species. Macroinvertebrate organisms which utilize the surface of the water for respiration are included in this classification.

TOLERANT: Organisms which not only have the ability to survive under a wide range of environmental extremes but are generally capable of thriving in water of extremely poor quality and even anaerobic conditions. Tolerant organisms are often found in great abundance in areas of high organic pollution.

The environmental classification system used to evaluate stream quality is defined by the E.P.A. as follows:

Stream Classification No. 1: (Balanced Environment) Intolerant organisms were many in numbers and species (more or equal to numbers) than other forms present. Intolerant species present greater than or equal to 50%. Moderate, Facultative and Tolerant species present less than or equal to 50%.

Stream Classification No. 2: (Unbalanced Environment) Intolerant organisms were less in number than other forms combined, but combined with moderate forms may outnumber tolerant forms. Intolerant species present less than 50% but not less than or equal to 10%. Moderate, Facultative and Tolerant species present greater than 50%.

Stream Classification No. 3: (Semi-polluted Environment) Intolerant organisms were few or absent. Moderate and/or Facultative organisms were present. Intolerant species present less than 10%. Moderate, Facultative and Tolerant species present greater than 90%.

Stream Classification No. 4: (Polluted Environment) Intolerant organisms absent, only tolerant organisms present or no organisms present. Facultative forms may be present. Tolerant present 100%

Organisms which are not adapted to a polluted environment were collected as a result of drift and are not representative. Water samples were taken from each site using internal BOD bottles at a depth of at least two inches below the surface of the water. DO was determined in parts per million (ppm) using the No. 54 YSI dissolved oxygen meter. BOD was determined by the five day incubation procedure outlined in "Standard Methods." Dilutions of up to 75% were necessary during periods of high organic load as indicated by increased amounts of algae and temperature. Both DO and BOD tests were conducted at the Charleston Sewerage Treatment Plant with instruments and techniques certified by the Illinois E.P.A. Water temperature was determined by a glass mercurial thermometer approximately one inch above the bottom substrate. Chemical tests for Nitrates, Nitrites, Ortho Phosphates, Hardness and pH were conducted using the Hach Kit Color filter series. Techniques were carefully kept uniform throughout the study so that discrepancies with the Hach Kit and actual quantities would be the same throughout the study, thus trends in the data would be more easily discernable. All chemical determinations were made immediately after sampling was concluded for that day. Water samples for chemical tests other than (BOD) and (DO), were transported in one liter polyethylene bottles.

LOCATIONS AND PHYSICAL CHARACTERISTICS

Riley Creek originates from two drainage ditches approximately one and one-half miles north of Mattoon, Illinois. It flows as an intermittant stream from west to east for approximately two miles to the first sampling site. At this point it is classified as a permanent stream. Approximately two miles from this point it passes under Interstate Route 57. It continues flowing through agricultural, feedlot, pasture and rural residential areas which encompass the last five sampling sites. Riley Creek merges with Cassel Creek about one-half mile north of Illinois Route 16 which eventually flows into Kickapoo Creek, a major tributary of the Embarrass River.

Sampling Site No. 1: Located in the S.E. 1/4, Sec. 6, T. 12N R. 7 E. fifty feet upstream from roadbridge. This site has tree lined banks with a mud bottom littered with rocks which were thrown into the stream from adjacent fields. The field on both sides of the site are under cultivation in either soy beans or corn. Soil associations for this site are in the "Dana" group. These are dark colored soils, moderately well drained, and sloping, formed of one and one-half to three feet of silty material over loamy material. There is usually a seasonally high water table one to two feet below the surface. Dana soils are suited for use as cropland or pasture. The sloping contour is a limitation however, when used as septic tank filter fields.

Sampling Site No. 2: Located in the S.E. 1/4, Sec. 4, T. 12N R. 7 E. 100 feet upstream from roadbridge. The stream banks are grass lined for approximately 15 feet to the edge of cultivated fields on both sides of the stream. The bottom substrate is mud and sand, however there is a riffle at the uppermost extent of the site. The fields on both sides of the stream are under cultivation in either soy beans or corn. The soils of the area are in the "Dana" series as previously discussed.

Sampling Site No. 3: Located in the S.W. 1/4, Sec. 1, T. 12 N. R. SE. 150 feet upstream from the roadbridge. This site borders the Charleston City Dump and collects much trash and debris from that source. There is a constant movement of earth on the dump site which adds to runoff into the stream, characterized by a 100% mud bottom strewn with trash. The stream banks are tree lined and the fields on the east side of the stream are cultivated in corn. The soil types of the area are in the Fincastle-Xenia series. These are light colored soils, poor to moderately drained, nearly level to gently sloping soils formed in one and one-half to three feet of silty material over loamy material. Fincastle-Xenia series soils are classified as moderately to slowly permeable soils.

Sampling Site No. 4: Located in the N.E. 1/4, Sec. 12, T. 12N., R. SE. 1/2 mile upstream from roadbridge on Route 316. This site has tree lined banks bordered by pasture on the south side and a small strip of cultivated corn field and Route 316 on the north side. The bottom substrate consists of sand and silt in the pool area and riffles with large rocks and cobble stone at the upper end of the site. The soils associated with this site are the Russel-Miami type which are light colored, well drained, gently rolling soils formed in less than three feet of silty material over loamy material. This type of soil is especially characterized by its moderate sloping form.

Sampling Site No. 5: Located at the N.E. 1/4, Sec. 17, T. 12N., R 8E. This site is located approximately 1/4 mile south of the Charleston Golf Course. The banks of the stream are tree lined and there is pasture surrounding the entire area. The bottom substrate is mud and sand and there exists a small riffle area at the lower portion of the sampling site with cobble size rock. There is little cultivation occurring in the immediate area of the golf course. The soil type of the area is the Strawn-Lawson Association which is light colored, well drained, sloping soils on the uplands adjacent to dark colored, somewhat poorly drained, nearly level soils on the bottom lands. This type of soil is maintained mostly as woodland or pasture. The limiting factor to this type of soil is the flooding or erosion problems.

Sampling Site No. 6: Located in the S.W. 1/4, Sec., 16, T. 12N., R 8E. 1/4 mile north of Route 16, 100 feet below the confluence of Cassel Creek. The stream banks are eroding due to usage by livestock for watering. Pasture surrounds the entire area. The bottom substrate is sand and gravel and there is a riffle area just below the convergence of the two streams which provides a natural mixing zone. The soils of the area are in the Strawn-Lawson series previously discussed.

DISCUSSION

One of the primary objectives of this survey is to record various water quality parameters that directly or indirectly effect macroinvertebrates in the Riley Creek stream ecosystem. The values for these parameters will be discussed on the basis of their effects on the numbers of taxa and individuals and their tolerance levels. The values for these parameters appears in figures 1-28 and tables 1-3. Each parameter will also be discussed separately.

WATER QUALITY PARAMETERS

Temperature

Temperature is a limiting factor in all aquatic ecosystems. It affects biotic as well as abiotic factors through the chemical phenomenon of reaction rate. It primarily effects enzyme reactions of the biotic community (plant and animal) and places limits on tolerance to temperature variation which in turn affects the interrelationships between plants and animals in the aquatic environment, Welch, (1952). Equally important is the function of temperature on other chemical parameters present in the awuatic environment. Water temperature directly affects the solubility of gases, especially carbon dioxide (CO_2) and oxygen (O_2) proportionately with temperature. Therefore, temperature affects the amount of O_2 and CO_2 present in the water which directly affects macroinvertebrate populations and plant life. High temperatures along with an increase in organics are conducive to an increase in growth of many aquatic plants which, in growth and death, effect the quality of the water and the organisms which dwell within.

The temperatures recorded on Riley Creek vary from 1.0° C to 28° C according to season, tributaries and physical contour of the stream itself. Sites near springs close to the head waters had cooler temperatures than areas of standing water, especially in the spring. Figures 8, 9 and 10 show a warming trend from April to July at which time volume and flow were minimal. In October and November the temperature steadily decreased and ice formed on the surface in November. The only extreme that occurred during any one sampling period occurred in November at station No. 6, below the confluence with Cassel Creek. Cassel Creek receives effluent from the Charleston Sewer Treatment Facility and thus maintains a higher temperature during cold weather.

BIOLOGICAL OXYGEN DEMAND (B.O.D.)

The biological oxygen demand (BOD) is defined by the American Public Health Association, (1975), as the relative oxygen requirements of waste-waters, effluents and polluted waters. BOD is the indirect measurement of oxygen used by micro-organisms during organic decomposition and as such is an indicator as to the relative amounts of organics present in the water. BOD values, (figures 1-4 and table 1), ranged from 1.5 in April to 8.0 in October and November. Spring values at low levels are primarily due to the fact that microbial communities are not fully developed because of low water temperatures and spring flooding has scoured the substrate of the majority of decomposing plant detritus. Also, BOD levels remain low in Spring compared to Fall because of the growth period occuring in the aquatic plants taking place at this time of year compared with death and decomposition in Fall and Winter.

Other sources of increase in BOD, as seen in fluctuations on table 1 and figure 4, may be the result of feedlot and fertilized field runoff which would peak in May according to rainfall. Several areas were determined to be possible point sources of organics which would influence BOD levels as well as other chemical parameters. Number one would be the intensive cultivation of fields surrounding the head waters and first two sampling sites. These would be sources of Herbicides and nitrogenous fertilizers used in corn and soy bean production. A second point source is a feedlot approximately two miles upstream from sampling site number two. This particular source has the effluent from 40-60 hogs with the stream running directly through the feedlot area. The third possible source is the county sanitary land fill. Riley Creek forms a border on the north side of the dump where there is evidence of much runoff from excavation. The seepage from rainfall through the dump area and into the stream via ground water is also a possible source which was not investigated. The fourth source of organics is the effluent from the Charleston Sewerage Treatment Plant which enters Riley Creek via Cassel Creek just above the sixth sampling site. The sewerage effluent is monitored and effluent quality is controlled, however, significant variances in water quality were noted at site number six, (figures 1-28 and tables 1-3). The effluents from all four point sources effect BOD's as well as other chemical parameters at each sampling site and water quality of Riley Creek in general.

DISSOLVED OXYGEN (D.O.)

The volume of oxygen dissolved in water at any given time is dependent upon the temperature of the water and the partial pressure of the gas in the atmosphere in contact with the water and the concentration of dissolved salts (salinity) of the water. (Reid, 1961).

The quantity of oxygen is also affected by respiration of aquatic plants diurnally and the respiration by aquatic organisms. As is well known, low levels of D.O. affect directly the macroinvertebrate communities in numbers of taxa and individuals as determined by a diversity value. Aerobic bacteria require oxygen to break down organic matter thus depriving other aquatic organisms of an oxygen supply. Dissolved oxygen at the first sampling site was found to be, for the most part, significantly lower than values at the other five sampling sites during each of the six sampling periods. Reasons for this could include water temperature, volume, flow rate, ice cover and B.O.D. Spring samples in April, May and June were taken from the site at a period of high water, cool temperatures and minimal amounts of decomposition and runoff. These samples yielded D.O.'s well above the recommended limit (PPM) for maintenance of an aquatic community. However, July, October and November sampling periods were characterized by conditions of little rainfall, thus minimal volume and flow, and with the development of large amounts of filamentous algae clinging to rocks of the substrate is usually indicative of a heavy organic load. The first site was also completely frozen over in November which would prevent oxygen exchange with the atmosphere. Sampling site number six maintained a higher mean dissolved oxygen value than other sampling sites. The fact that there was a greater volume and flow maintained throughout the survey including a number of riffles is probably a factor. There are also no other point sources of pollutants below the sewerage treatment plant outfall in Cassel Creek which would decrease dissolved oxygen. The United States Environmental Protection Agency (USEPA) (1973), has proposed minimal concentrations of dissolved oxygen at (5.8 PPM at 25.7°C) to protect aquatic life.

pH (HYDROGEN ION CONCENTRATION)

The pH of water is its degree of acidity and alkalinity as expressed by the log of the reciprocal of the hydrogen ion concentration. The pH of most natural waters falls within a range of 4.0 to 9.0, (American Public Health Association 1971). Values obtained during the study indicate the stream to be slightly alkaline. Means levels above 7.0 (table 3) at all sampling sites, are due to the fact that CO_2 is being bound in a bicarbonate form and not lost to the atmosphere in the riffle areas where surface tension is broken. The point sources of pollution as indicated earlier, are also possible causes for fluctuation in pH especially in the area of the first and second sampling sites. Here the addition of nitrogenous fertilizers to the stream via high water table and many drain pipes from fields occurs, especially after periods of significant rainfall. The pH values for each sampling period are graphed on figures 11, 12 and 13 and the greatest fluctuations are indicated at the first and fifth sampling sites. However, the values recorded at all six sampling sites at each period were within a range of 6.0 to 9.0 (with 0.5 natural variance) as suggested by the United States Environmental Protection Agency (1973) as a standard for a healthy aquatic environment.

NITRATES (NO_3) NITRITES (NO_2)

Nitrogen is recognized as one of the most important elements available to living systems. Nitrogen is used as a nutrient in organic form to plants and animals in the aquatic environment.

However, levels of nitrogen exceeding usable amounts to plants and animals in a given area, has a toxic effect indirectly through the lowering of oxygen levels by the promotion of decomposition and unchecked plant growth. The forms of nitrogen present in Riley Creek are free nitrogen (N_2) in solution, nitrite (NO_2), ammonia (NH_4) and a variety of other decomposition products. The predominant nitrogen form is nitrate (NO_3), Hutchinson (1957). Hutchinson further lists possible sources of nitrogen compounds as:

1. precipitation of water surface
2. fixation in the water and its sediments
3. effluents including ground water, along with agricultural runoff, feedlot runoff and any other unnatural effluent introduced into the aquatic ecosystem.

The U.S.E.P.A. (1973) has proposed maximum levels for nitrate (NO_3) at 10.0 PPM for healthy aquatic environments. Values for nitrates on figures 14, 15 and 16 fluctuate greatly. Values in April, May, June and October exceeding the maximum EPA level values with determination up to 120 PPM indicative of a concentrated effluent entering the stream system. A combination of effluents from point source one (agricultural runoff) and point source two (feedlot runoff) can easily be considered the source of organics contributing to the high values. Biological indicators of these effluents could be seen as great masses of filamentous algae almost completely covering the stream bottom and hanging in profusion from the field drain tiles entering the stream. Nitrite values set by the U.S.E.P.A. (1973) are 1.0 PPM for public water supplies.

Graphs on figures 18, 19 and 20 show levels are mostly below maximum EPA levels except for sampling site number six which shows levels exceeding maximum scale values in June, July, October and November. The maximum value of scale was 0.2 PPM and exceeding this does not mean that values were greater than the EPA maximum. This fact, however, does indicate that NO_2 is being introduced into Riley Creek from other sources that don't occur along the stream from the head waters down to the sixth sampling site. It may be presumed that the source of extra nitrites comes from the sewerage treatment plant effluent where wastes are gathered from the City of Charleston, treated and released into Cassel Creek, which enters Riley Creek above the sixth sampling site. Nitrites may be extremely toxic to organisms due to interference with respiratory functions, however, there were no fish kills or drastic breakdowns in the benthic communities noticed below this source.

ORTHO-PHOSPHATES

Phosphorus (P) along with nitrogen is one of the most important constituents of living things on earth. Quantities of this element exceeding natural levels is as detrimental to aquatic environments as it is useful at lower concentrations. Phosphorus enters the aquatic community through the weathering of phosphorus bearing rocks, decomposition of organic material and commercial fertilizers which are of primary concern as ortho-phosphates. Large quantities of phosphates are removed from the water by phytoplankton in the form of orth-phosphates (Russel-Hunter, 1970). However, if levels exceed usable amounts the excess causes algal blooms, surface scum and foul odors. The levels of ortho-phosphates set by the Illinois State E.P.A. is 0.1 (.1 PPM) for domestic waters.

Values from the water samples fluctuated around this quantity throughout the survey. Principal sources of ortho-phosphates can be seen to affect sampling sites one and six. Point source one, with the addition of fertilizers around head waters and point source six, the addition of sewerage effluents from the Charleston Sewrage Treatment Plant above sampling site six may result in the values as indicated on figures 21, 22 and 23 and table 2. Ortho-phosphate levels exceeded the maximum on the Hach instrument scale of 2.0 PPM in May, July and November. This fact may be attributed to the runoff of fertilizer applications in spring, the effects of low water, concentrating the chemicals during the summer and ice covering the surface of the stream. Ice cover reduces light penetration and oxygen availability from the atmosphere, killing the aquatic plants, which increases decomposition supplementing high phosphate levels. Consistently high values were at the sixth sampling site from phosphates apparently emanating from the sewerage effluents.

TOTAL HARDNESS ($CaCO_3$)

The U.S.E.P.A. (1973) states that the term "hardness" serves a useful purpose as a general index of water type, buffering capacity and productivity, but should be avoided for use in determining water quality requirements for aquatic life without placing special emphasis on specific ions such as Calcium (Ca) and Magnesium (Mg). Magnesium is vital to plant growth and large quantities of calcium ions accelerates bacterial decomposition. The Illinois State Water Survey has classified hardness as milligrams of $CaCO_3$ for values as follows: 0-75, soft; 75-125, fairly soft; 125-250, moderately hard; 250-400, hard; greater than 400, very hard (Harmeson and Larson 1969). The total hardness for all sampling periods (table 2) ranged from 160 to 520 mg $CaCO_3/l$ which is moderately hard to very hard.

The mean values (table 2) also range from 250 to 350 which is classified as hard. The hard condition of the water is most probably related to a period of low rainfall (little dilution) according to seasonal variation.

TURBIDITY (JACKSON TURBIDITY UNITS OR JTU'S)

Turbidity as described by Reid (1961) is the degree of opaqueness produced by suspended particulate matter which limits light penetration. Turbidity creating matter in a stream system usually originates from the surrounding watershed in the form of runoff, especially from cultivated and feedlot runoff. Farm animals utilizing the stream for example, contribute to the turbidity between sampling sites one and two. Turbidity through suspended solids is directly and indirectly detrimental to aquatic organisms. Silt, sand and other debris has an abrasive effect on the bodies of certain organisms, and affects respiration. It also interferes with procurement of food by fish and other organisms. Turbidity affects the aquatic community by limiting light penetration to aquatic plants, reducing the quantity of oxygen produced and increasing the concentration of CO_2. Excessive turbidity in the form of siltation, causes an alteration of the substrate which may make it uninhabitable for species of the macroinvertebrate communities as well as other aquatic organisms. The U.S.E.P.A. (1973) states "acceptable conditions regarding color and turbidity of water are met if the normal variation point is not changed by more than 10% from its seasonally established norm and if so, no more than 10% of the biomass of photosynthetic organisms is placed below the compensation point by such changes."

The range of turbidity (table 2) was from 5 to 145 JTU's, however, the mean high for all sampling periods (table 2) was 47.3 JTU's which is acceptable by the E.P.A. standards. Extremes, shown on figures 27, 28 and 29 are located at sites 2, 3 and 4. This is due to the characteristics of the point sources as discussed. The first point source should be of primary concern, but with minimal rainfall, runoff would not enter in. The second point source, however, is of primary importance. The flow of the stream through the feedlot supporting 40-60 hogs allows for an effect on turbidity created by their use of the stream. The fifth sampling site almost consistently had the lowest turbidity value which indicates that the distance between the second site and fifth site gave suspended solids time to settle out in the pasture and woodlot watershed areas between those sites. In general, the physical-chemical parameters investigated indicate Riley Creek to be of rather poor water quality. Nitrates, nitrites and ortho-phosphate tests gave values beyond the range of their testing scales. Total hardness reveals that the quality of the water is "hard." Dissolved oxygen levels are as low as 0.7 PPM and B.O.D. ranges 1.4 to 32.4 mg/l B.O.D. pH values prove the water to be generally alkaline and turbidity is significant for the most part, according to the E.P.A. standards. All of these water quality parameters are directly or indirectly limiting on all aquatic organisms found in Riley Creek. A comparison of water quality parameters, physical characteristics of the substrate and watershed surrounding each sampling site, and numbers of taxa and numbers of individual macroinvertebrates follows.

MACROINVERTEBRATE FAUNA

In an ecological study such as this one, it is important to investigate all possible factors which influence the distribution and abundance of the organisms being considered. Riley Creek is a shallow stream running through areas of differing watersheds, having may different substrates. Many taxa of macroinvertebrates occur due to the wide variety of substrates available preferred by the organisms.

BRYOZOA

The genus Plumatella was found at sites number three in May and two in June. These organisms are characteristic of unpolluted, unsilted waters especially ponds and shallow lakes, (Pennak 1953). However, the Illinois E.P.A. classifies this particular genus as facultative in tolerance to pollution which coincides with locations in which it was found along the stream.

Plumatella was found on submerged woody substrates above the bottom sediment which would allow for more efficient respiration and ciliary feeding. The adult form was found only during these two sampling periods probably due to the fact that environmental factors, especially O_2, were at an optimum. At the onset of O_2 stress statoblasts were likely produced to allow the organism to endure the more rigorous environmental conditions.

NEMATODA

Sampling methods utilizing a number 30 U.S. standard sieve and the substrate preferences of nematodes were not conducive to obtaining an accurate account of the numbers and taxa of this group of organisms. Almost any collection of mud, sand or debris from the margins of lakes, brooks, ponds or rivers will contain nematodes of some abundance, (Pennak 1953).

Nematodes were found during every sampling period (Tables 5-28) at almost all sampling sites except during November. At that time, temperature levels were at a minimum and ice covered the surface of the stream. These organisms are associated with soft substrates and omnivorous or detritus feeding habits which is characteristic of semi-polluted waters. The E.P.A. classifies all nematodes as facultative in tolerance. However, this cannot be correlated with individual sampling sites due to their substrate preferences.

NEMATOMORPHA (Horse Hair Worms)

The adults are clumsy swimmers and writhe about in puddles and shallow marshes, lakes, ponds and streams, (Pennak 1953). The Illinois E.P.A. classifies these organisms as facultative in tolerance to pollution. Two genera of nematomorphs Gordius and Paragordius, were found at the first and last sampling sites during the October sampling period only. This fact may indicate that they can tolerate water quality at the lowest levels which are found at these two sites. These organisms are rarely found in great numbers due to their life cycle and drift should be taken into consideration as to the locations at thich they were found.

OLIGOCHAETA (Aquatic Earthworms)

The majority of true aquatic oligochaetes are found in the mud and debris substrates of stagnant pools, ponds, streams and almost every type of water system, (Pennak 1953). Their bodies are more delicate than their amphibious or terrestrial relatives so that obtaining specimens in good condition was difficult due to the sampling techniques used.

The particular genera found are considered tolerant to pollution by the Illinois E.P.A. and are observed to have a definite affinity for muddy substrates in areas of high organic loads as noted by the locations in which they were found. (Tables 5-28). Genera of the family Tubificidae including *Limnodrilus*, *Lumbriculus* and *Eclipidrilus* were collected. These worms were found primarily at the first two sampling sites, which indicates their preference for areas of high organic compounds, as substrates at all other sampling sites were conducive to their habitation, but did not have as high levels of organic compounds.

HIRUDINEA (Leeches)

Leeches are common inhabitants of ponds, marshes, lakes and slow moving streams, especially in the northern part of the United States, (Pennak 1953). The three genera of leeches found were *Helobdella*, *Placobdella*, and *Glossiphonia*. These were found in the greatest abundance at the first two sampling sites (tables 5-28). Having oral suckers these organisms prefer substrates partially submerged in organic detritus in the bottom sediments as occurs in the greatest amounts at the first sampling site. The Illinois E.P.A. classifies *Glossiphonia* and *Placobdella* as tolerant and *Helobdella* as facultative in tolerance to pollution. This correlates with the fact that leeches were found at the sites of the highest (BOD) in every sampling period where preferential substrate was available. Due to their morphology, the factor of drift is minimized through their clinging capabilities. The *Glossiphonia* are characterized as scavengers and detritus feeders while *Placobdella* and *Helobdella* are considered carnivores and associated with snails (snail leeches) which were also found in the greatest abundance at the first two sampling sites, (tables 5-28).

They also may occasionally take a blood meal from frogs, fish, turtles and man which may be a factor in their distribution.

CRUSTACEA

ISOPODA (Aquatic Sow Bugs)

Isopoda in the United States are, for the most part, restricted to fresh water streams, brooks, springs and subterranean waters, (Pennak 1953). *Lirceus lineatus* was the species found consistently at the sixth sampling site where they were collected from partially submerged logs and the underneath side of over-hanging grasses. This may be correlated with the occurrence of dissolved oxygen values which were maintained as high or higher than the mean values for all sampling periods, (Table 1). The mixing-factor plus the greater volume of water maintaining a relatively high dissolved oxygen, and availability of preferred substrates are the combined factors conducive to the presence of this particular organism. Isopods are characterized as scavengers and algae feeders which is indicative as to the locations at which they were found. The Illinois E.P.A classifies the genus *Lirceus* as moderate in its tolerance to pollution, which would correlate with its association with the sixth sampling site as compared to the other five sites, according to season.

AMPHIPODA (Scuds)

Fresh water amphipods occur in a wide variety of unpolluted lakes, ponds, streams, brooks, springs and subterranean waters, (Pennak 1953). The Illinois E.P.A. classifies *Hyalella*, the only genus found, as intolerant to pollution. *Hyalella* was never found at the first or third sampling sites, probably due to the lack of a preferred substrate, rather than the low water quality. The greatest abundance was found at the fifth sampling site, (tables 5-28), where water quality was highest in woodlot pasture watershed and preferred substrates were available in the form of overhanging grasses, roots and considerable masses of leaves and detritus. Drift is of no consequence to the distribution of this genus due to their clinging abilities. The presence of amphipods contradicts chemical parameters tested. Apparently, there has been some adaptation to non-typical niches in the stream system by utilizing substrates near the surface of the water, especially below existing riffle areas. They may have also developed an acclimation to pollutional levels in the stream system over a period of time.

DECAPODA (Crayfish)

Crayfish are characteristic and common inhabitants of most types of running waters including shallows of lakes, ponds, sloughs, swamps, streams, rivers and subterranean waters (Pennak 1953). The only genus found throughout the entire stream system was Orconectes which is classified as intolerant to pollution by the Illinois E.P.A. It is found intermittantly during all sampling periods at all sampling sites except the first. Preferred substrates are rocks and debris, which exist at the first sampling site, thus the conclusion can be made that the chemical parameters are a limiting factor at this site. Especially limiting would be the low D.O. values and water levels that fluctuated seasonally. This may allow for periodic migration upstream to the first site, but would not be conductive to permanent habitation.

INSECTA

PLECOPTERA (Stoneflies)

For the most part, stonefly nymphs are rather sluggish insects which occur in masses of algae, leaves, stones and other debris in almost every kind of lotic environment. They are only found where there is an abundance of oxygen and many species are specific in ecological preferences (Pennak 1953). The only genus found throughout the survey was *Acroneura*, which is classified by the Illinois E.P.A. as intolerant to pollutants. *Acroneura* was found at all sampling sites at least once during the months of April, May, June and July excepting the first sampling site. As previously discussed, the first sampling site has been an area of low water quality especially in D.O. values. This is the primary reason for their absence in the vicinity of the first site. Their relative abundance throughout the survey did not exceed two individuals for any sampling site which would indicate competition from other organisms or low tolerance to pollutants effecting their relative abundance. The great majority of adults emerge between the months of August and November due to life cycle which would be a primary reason for their complete absence during the months of October and November. Correlated with this fact would be the minimum levels of water quality occuring during these months, (figures 1-29). Generally, there were substrates at all sampling sites that were habitable for these organisms.

EPHEMEROPTERA (Mayflies)

Mayflies have a world-wide distribution but are only found in the vicinity of bodies of fresh water in which the immature stages develop. In contrast to the adults, the nymphs show considerable variations and adaptations to their specific habitats (Pennak 1953). A total of four families were encountered and the Illinois E.P.A. has classified their tolerance to pollution (tables 5-28). Only one individual of the genus Hexagenia was found at the fifth sampling site in November. This genus is of the family Ephemeridae which is usually found in great abundance. In the spring, high water scours the bottom sediments and carries away debris which is their preferred habitat. Other genera have developed greater clinging abilities, which allows them to inhabit rocks and submerged logs on which the great majority of individuals were found. It should be noted that there were no mayfly nymphs whatsoever, found at the first sampling site which coincides with low values of water quality parameters, especially that of oxygen. The Illinois E.P.A. classifies the majority of the Emphemeroptera as intolerant, including the genus Hexaginia. The abundance of this genus fluctuated about equally between sampling sites three-six at all sampling periods, (Tables 5-28). The genus Baetis of the family Baetidae and the genus Caenis of the family Caenidae had approximately the same occurrence as Heptagenia but with much less abundance. Water quality parameters and possibly competition from Heptagenia were the limiting factors for the genera Baetis and Caenis. Evidence for this is based on the fact that at all sampling sites there were ample substrates of the types preferred, rocks, submerged logs and leaf litter, and an ample food supply of algae and other aquatic vegetation. Another factor to be considered must be emergence time. Pennak (1953) describes Spring, and Summer as times of emergence, primarily controlled by water temperature. Unfortunately, this does not allow for the pin-pointing of times for emergence of each genus.

ODONATA (Dragonflies, damselflies)

Odonada naiads are commonly found on submerged vegetation and the bottoms of ponds, marshes and streams and in the shallows of lakes, but rarely in polluted waters (Pennak 1953). There were four families collected with a single genus in each. One genus (Calopteryx) is not classified by the Illinois E.P.A. This genus was found at sampling sites three and six in April and May. In contrast specimens of the family Libellulidae was found at sampling sites one, two and six during all sampling periods except June. Their abundance was significantly low and it is thought that with the sampling techniques used their procurement was determined mostly by chance. The genus Aeshna of the family Aeshnidae was found only once at the sixth sampling site in October. This genus is moderately tolerant due to the fact that intolerant genera occurred in much greater abundance in the same area. The genus Ischnura of the family Coenagrionidae was found throughout the survey in almost all sampling sites except the first, (Tables 5-28). This genus occurred with the greatest abundance which is contradictory of its classification as intolerant by the Illinois E.P.A. and the quality of the water in which it was found.

Generally, odonata nymphs are carnivorous, feeding on various forms of invertebrates. This fact may be associated with their lack of abundance at the first two sampling sites. Poor water quality would inhibit the production of the invertebrate forms on which the odonates feed. Substrate preference of odonates varies, but there were inhabitable substrates of rocks, logs and debris in the vicinity of all sampling sites.

HEMIPTERA (True Bugs)

There were three families of true bugs found, each represented by a single genus (tables 5-28). The Illinois E.P.A. classifies all three as facultative in tolerance to pollution. The genus *Velia* is noted to roam the entire surface of the body of water on which it lives and is almost always found on floating algae and plant rafts (Pennak 1953). This particular genus was found only once during the entire survey, at the second sampling site in June. The fact that it occurred only once is not likely due to the fact that they are facultatively tolerant. There was little or no competition by other forms inhabiting this particular habitat. The genus *Gerris* is characterized as a skater or strider over the water surface. Species of *Gerris* were seen at almost all sampling sites especially in May, June and July, but due to their elusive nature and the sampling techniques used, few were collected. Their presence mainly on the surface of the slower moving, deeper pools, was noted. The *Hespercorixa* are noted for their swift swimming abilities. They have long, flattened, hairy hind legs which serve an oar-like function. This genus was found during June, October and November at the second through the sixth sampling sites. As with the *Gerris*, the elusiveness of these forms makes capture difficult and abundance difficult to discuss.

All of these genera are strict predators and feed primarily on small terrestrial and aquatic insects and entomostraca (Pennak 1953).

TRICHOPTERA (Caddis Flies)

There were two genera, Cheumatopsyche and Hydropsyche, which are both considered moderate in tolerance by the Illinois E.P.A. It is thought that caddis flies produce one or two generations per year especially in higher latitudes. The greater portion of the life history is spent as a larvae in which form it overwinters. The larvae emerge as adults between May and September (Pennak 1953), which causes difficulty in assessing occurrence and abundance. The larvae are found primarily in riffle areas where currents bring food and facilitate respiration. Both genera occur with limited abundance at sampling sites two through six during the sampling periods of April, May, June and July with constantly decreasing numbers as the survey progressed. Hydropsyche and Cheumatopsyche occurred simultaneously at several sampling sites which would indicate similar tolerance to the limiting factors in water quality. There was, however, no occurrence at the first sampling site. This may be due to their inability to complete the life cycle because of seasonal water fluctuations or because of the poor water quality. Each sampling site contained riffles and substrate inhabitable by these organisms. Because of their omnivorous feeding habits, food supply was not a limiting factor.

COLEOPTERA (Beetles)

There were five families of coleoptera encountered during the survey. (The Elmids, a medium sized family in which all adults and larvae are aquatic except for two genera Pennak 1953).

The genera of Elmidae were, *Cylloepus*, *Stenelmis*, and *Dubiraphia*. All of these genera crawl about the substrate, slowly clinging to the substrate with their tarsal claws, feeding on vegetation and debris. The second family, Dryopidae, is small and all larvae and adults are aquatic. The only genus found was *Helichus* which is the largest of the five common genera. These have habits and a general morphology similar to the Elmidae, however, the adults sometimes leave the stream to fly about at night. Feeding is primarily upon algae film on the stream substrates. The Hydrophilidae are a large family with the majority of adults and larvae being aquatic. These beetles are common in quiet pools, which are shallow, with abundant vegetation. They feed on most forms of living or decayed plant material. The genera encountered were *Tropisternis*, *Helophorus*, *Enochrus* and *Hydrobius*. The Haliplidae are a small family in which all adults and larvae are aquatic. They are normally found crawling about masses of filamentous algae and other vegetation. Haliplids are chiefly vegetarians, although, some may feed on animal material. Genera encountered were *Haliplus* and *Peltodytes*. The fifth family encountered were the Dytiscidae. This is the largest aquatic family, highly adapted, with all adults and larvae completely aquatic. This group is exclusively carnivorous and voracious, feeding on all kinds of smaller aquatic organisms such as dragonfly nymphs, tadpoles and even small fish. The only representative genus was *Hydrovatus*. These five families and their genera vary in abundance according to habitat, season and water quality, however, the Illinois E.P.A. classifies all beetles found as facultative in tolerance to pollution.

There is great variation in their occurrence according to sites and sampling periods, (tables 5-28). It is significant to note that although having a facultative tolerance, there is no occurrence of any beetles at the first sampling site. This supports the suggestion that water quality parameters are the limiting factors affecting the Coleoptera at this site. There are ample habitats for all forms of coleoptera found in the vicinity of all of the sites sampled, however, the first sampling site with its low water quality quite possibly could not produce food for the predaceous forms.

DIPTERA

CULICIDAE (Mosquitoes)

This is a large family, all larvae are aquatic, with world wide distribution. Culicidae larvae feed primarily upon algae, protoza and bits of organic debris. The species Anopheles punctipennis and genus Theobaldia were collected. As larvae, they usually lie quietly just below the surface of the water in a horizontal position. Species of the genus Anopheles are usually found in all types of non-stagnant water, from very small puddles to streams, and ecological distribution shows no correlation with pH. Many forms can tolerate a range of pH from 5.0 to 9.0. The Illinois E.P.A. classifies Anopheles punctipennis as tolerant to pollution, however, genus Theobaldia is not classified. Each was collected only once, Anopheles, at the third sampling site in July and Theobaldia at the fourth sampling site in October. Being tolerant to pollution, there is no correlation between their lack of abundance and water quality. However, the crudeness of the sampling techniques, the insects delicate bodies, and their life history and emergence time are factors to be considered.

Swirling substrate samples in the number 30 U.S. standard sieve for example, would crush the delicate bodies. Emergence in early spring could be a partial reason for lack of their being collected as well.

SIMULIDAE (Black Flies)

This is a small but prolific family of world wide distribution. The larvae are found in the shallows of streams where the current is especially swift. Their heads are directed downstream and their posterior is tightly attached to rocks or vegetation (Pennak 1953). The Illinois E.P.A. has classified the only genus Simulium as having a moderate tolerance to pollution. Simulium has been found at all sampling sites throughout most of the survey in relatively great abundance, (tables 5-28). This form feeds primarily upon plankton and other organic debris, which it filters through an anterior fan. Abundant quantities were present at all sampling sites.

CHIRONOMIDAE (Midges)

Adults of the midges commonly occur in swarms near bodies of water, and are especially drawn to lights at night. The larvae occur everywhere in the aquatic vegetation and on the bottoms of all types of bodies of fresh water, some solitarily and others in great abundance. The larvae are chiefly herbivorous and feed on algae, detritus and higher aquatic plants. Fifteen representative genera were identified. The most abundant of these, Chironomus, the Illinois E.P.A. classifies as tolerant to pollution. The remaining fourteen genera are classified as moderate or facultative to pollution, or not classified at all. The greatest numbers of all genera occurred in the spring months of April and May, (tables 5-28).

This was followed by a gradual but continual decrease in occurrence and diversity as the survey progressed owing primarily to emergence time and life history. This group plays an intricate role as a food organism for the macroinvertebrate community and fish. The great abundance of these organisms in relation to others is attributed to the common availability of stream substrate of the kind they prefer along with plentiful food supply present due to high organic load.

HELEIDAE (Biting Midges)

This group is known for their irritating bite. They usually are present around lakes and seashores. The elongate larvae may be found in a number of habitats, however, they are most abundant around floating masses of algae. The genus *Culicoides* of the family Heleidae was collected. It is the most common genus. A single individual of this genus was found at the first sampling site in May. This distribution does not make it appear to be a good indicator of stream quality. The Illinois E.P.A. considers this genus facultative in its tolerance to pollution which would correspond with the water quality of the first sampling site in May.

STRATIOMYIIDAE (Soldier Flies)

This family has few species with aquatic immature stages in which the eggs are deposited on aquatic plants or debris in shallow ponds and streams. Food includes algae, organic debris and small metazoa. The representative genus *Stratiomyia* is classified as tolerant to pollution by the Illinois E.P.A. A single individual was found at the sixth sampling site in October and at the first sampling site in November, (Tables 5-28).

The low occurrence does not lend itself to making the genus Stratiomyia a representative indicator organism, especially on the tolerant level. This group, having few aquatic species, is naturally sparse, so its value as an indicator is limited.

TABANIDAE (Horse Flies)

The Tabanidae is a large family of world wide distribution. The eggs are laid in masses of foliage and debris at the edge of the water so when they larvae emerges it drops into the water. It resides in the aquatic environment for up to three years and then crawls out of the water and burrows into the dry earth above the water line to pupate. Species collected were of the genera Chrysops and Haematopota, which are both classified by the Illinois E.P.A. as facultative in tolerance to pollution. Numbers of the genus Chrysops feed on organic debris while species of Haematopota are predaceous and feed on snails, oligochaets and insect larvae. Both genera were found in October, Chrysops at the third sampling site, and Haematopota at the sixth sampling site. This evidence of occurrence and distribution has no relevance to water quality parameters due to the fact that these forms are naturally sparse in distribution.

ANTHOMYIIDAE (Anthomyiids)

The anthomyiids are closely related to house flies and have relatively few genera that are aquatic. A single individual of the genus Limnophora was found in June at the third sampling site. This genus is found to be facultative in tolerance by the Illinois E.P.A. Due to its scarcity, its value as an indicator organism is limited. Water quality and substrate relationships cannot here be associated with its insignificant occurrence.

GASTROPODA (Snails, Limpets)

In almost every type of fresh water environment there exists a characteristic population of gastropods. The majority of fresh water gastropods have a spiral or discoidal shell except for the limpets, whose shell is in the shape of a low cone. The majority of fresh water gastropods are omnivorous, scraping algae from the hard substrate with their radula as they glide along a mucus trail secreted by the foot. There were five families of gastropods encountered in the survey, the first and most abundant of which was Physidae, represented by the genus Physa. The Illinois E.P.A. considers this genus tolerant to pollution which coincides with its great abundance at the first sampling site during periods of very poor water quality, (tables 5-28). The second family, Lymnaeidae, represented by Lymnea had about the same frequency of occurrence as Physa but did not equal it in abundance, (tables 5-28). Lymnea is considered facultative in tolerance. Both of these genera, Physa and Lymnea being algae feeders and having a relatively high tolerance level, would be expected to be found in the vicinity of the first two sampling sites where increased organic loads promoted heavy growths of algae. The third family Planorbidae, represented by the genus Gyraulus, occurred only once in April at the second sampling site. Three individuals were found. This number of specimens would not make their presence indicative of the facultative tolerance status assigned to it by the Illinois E.P.A.

The fourth family, Valvatidae, is represented by the genus Helisoma, which is not classified as to tolerance status. However, other species of Valvatidae are considered intolerant. This genus only occurs twice at the first sampling site in June and July during which time water quality was approaching its minimal level.

This shows that the intolerant status probably does not apply to this particular genus. The fifth family Ancylidae, was represented by the genus *Ferrissia*. This genus of limpet was found in April, May, July and November at all sampling sites except for site number one. It can be deduced that with the occurrence of this genus at all other sampling sites, and taking into consideration food and inhabitable substrates available, poor water quality is the only alternative as a limiting factor of this organism at site number one.

PELECYPODA (Clams, Mussels)

The pelecypods, which are bivalve mollusks, are entirely aquatic and found in abundance in large river systems. Pelecypods move over and through the substrate by contractions of the intrinsic muscel of the foot. Two families of pelecypods were found, the first, Sphaeriidae, is represented by two genera, *Sphaerium* and *Pisidium*. These two genera occurred with approximately the same frequency and abundance throughout the survey. Both are considered moderately tolerant forms which would explain their existence at all sampling sites except the sixth. Filter feeders such as pelecypods are known to take in and retain impurities from their surrounding waters making them unfit for consumption. It can be suggested that the sewage effluent entering Riley Creek via Cassel Creek above the sixth sampling site may contain substances which would be limiting or toxic to organisms with filter feeding habits owing to their low occurrence at the sixth site.. The second family, Lampsilidae, was represented by a single individual of the species *Leptodea fragilis*. It was collected at the second sampling site in October. This species single occurrence reduces its value as a significant indicator. The Illinois E.P.A. also has no classification as to the tolerance for this particular species.

CONCLUSION

It has been determined, through testing water quality parameters and assigning tolerance status values to the macroinvertebrates to obtain stream site classifications, that Riley Creek is in an unbalanced condition. The stream in the vicinity of the headwaters has proven to be semi-polluted. Four point sources of pollution have been observed as direct effluents to Riley Creek and their influence is directly responsible for stream conditions and water quality. Stream conditions of this type are common for a waterway of this size in the midwest as noted by personal observation. Heavily agriculturalized areas will produce runoff into the waterways which cannot be prevented to any great extent. Other point sources, such as feedlots centered around the stream or sewage effluents, could be cleaned up or eliminated. Water quality and stream conditions in general on Riley Creek could be improved with modifications of the point sources of pollutants.

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APPENDIX

DATA FOR WATER QUALITY PARAMETERS

FIGURES 1 - 4	BOD values in mg/L for sites 1-6 for each of the six sampling periods plus mean values.
FIGURES 5- 7	Dissolved oxygen values in ppm oxygen for site 1-6 for each of the six sampling periods.
FIGURES 8-10	Temperatures (^{o}C) for each sampling site for all sampling periods.
FIGURES 11-13	Hydrogen Ion Concentration (pH) values for each sampling site in all sampling periods.
FIGURES 14-17*	Nitrate values as ppm NO_3 for each sampling site during each sampling period plus mean values.
FIGURES 18-20*	Nitrite values as ppm NO_2 for each sampling site during each sampling period.
FIGURES 21-23*	Ortho-Phosphate values as ppm P, for each sampling site during each sampling period.
FIGURES 24-26	Total Hardness values as mg/L $CaCO_3$, for each sampling site during each sampling period.
FIGURES 27-29	Turbidity values as JTU's, for each sampling site during each sampling period.
TABLES 1-3	Mean physical data.

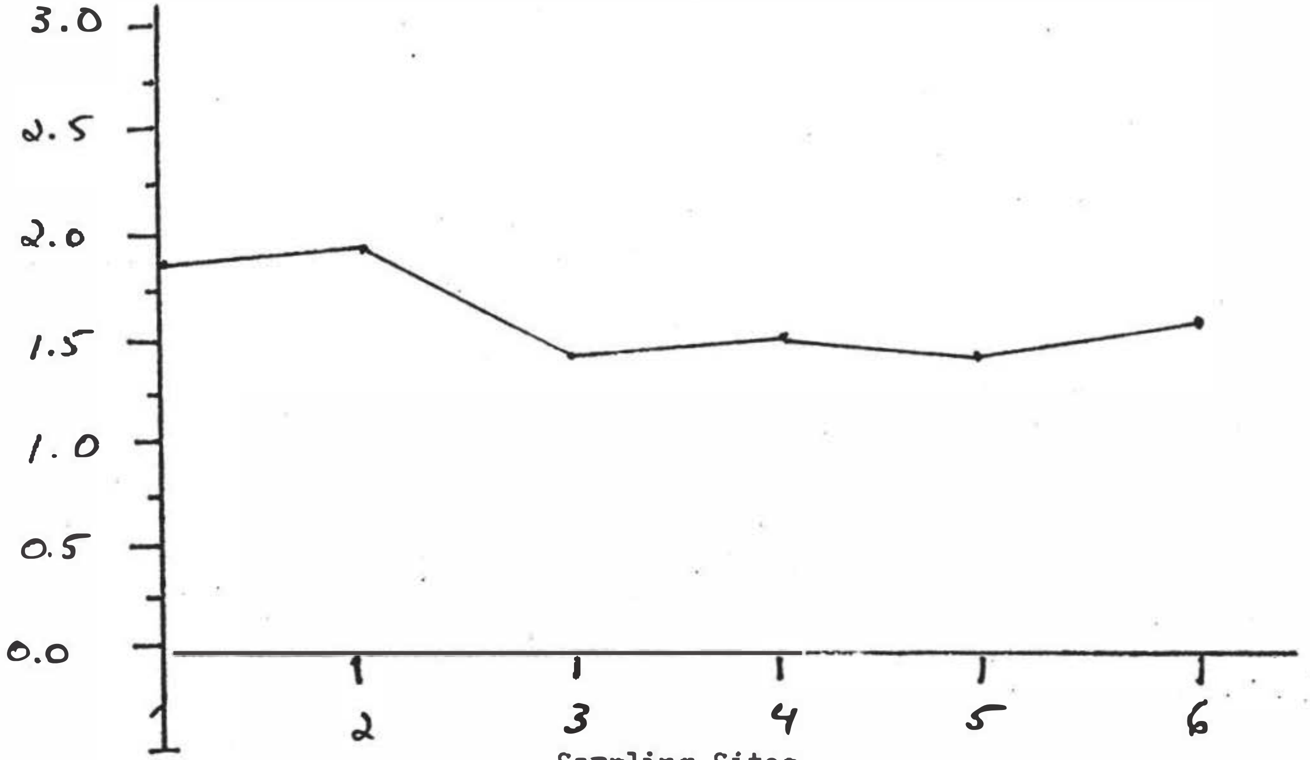
* DOTTED LINE INDICATES VALUES EXCEEDED MAXIMUM ON SCALE.

MACROINVERTEBRATE DATA

FIGURES 30-32	Numbers of taxa for each sampling site per sampling periods.
TABLE 4	Stream site classification
TABLES 5-28	Each individual taxa categorized as to tolerance per sampling site for each sampling period.

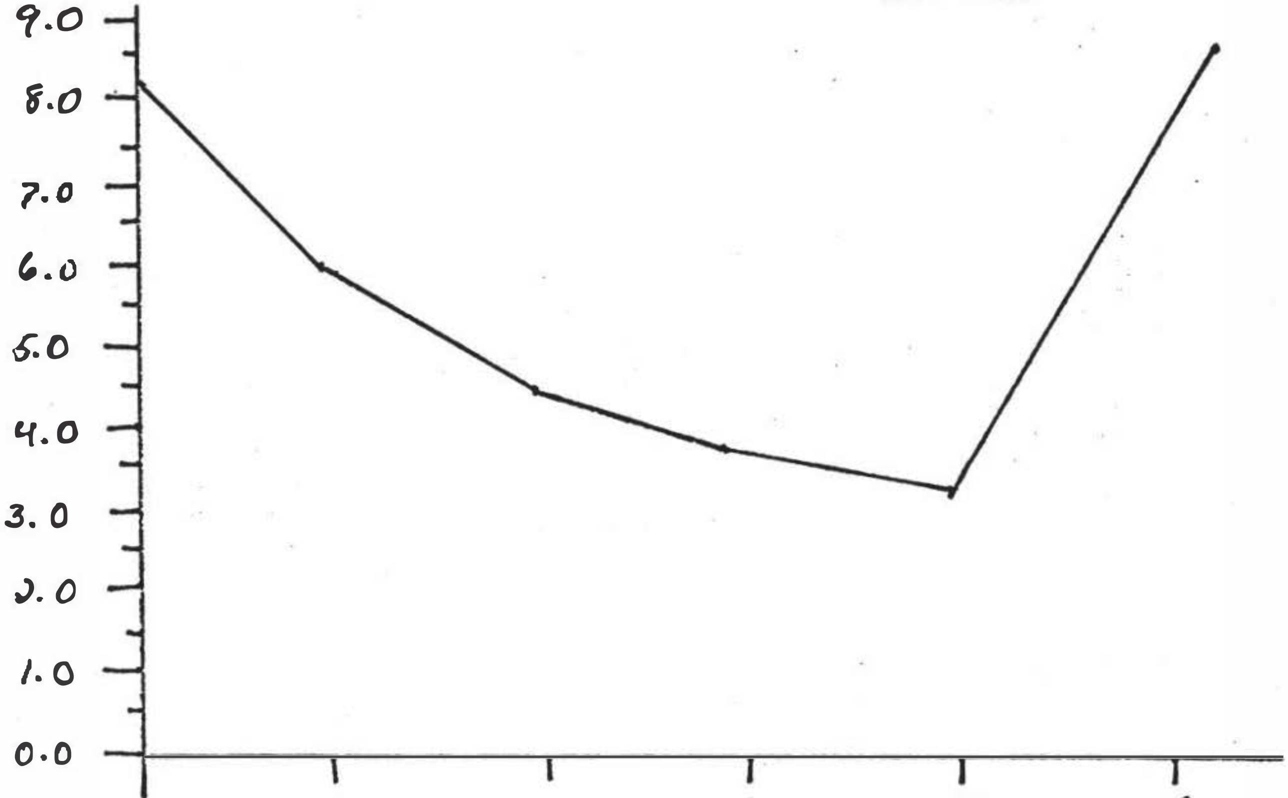
Figure 1.

APRIL BOD.



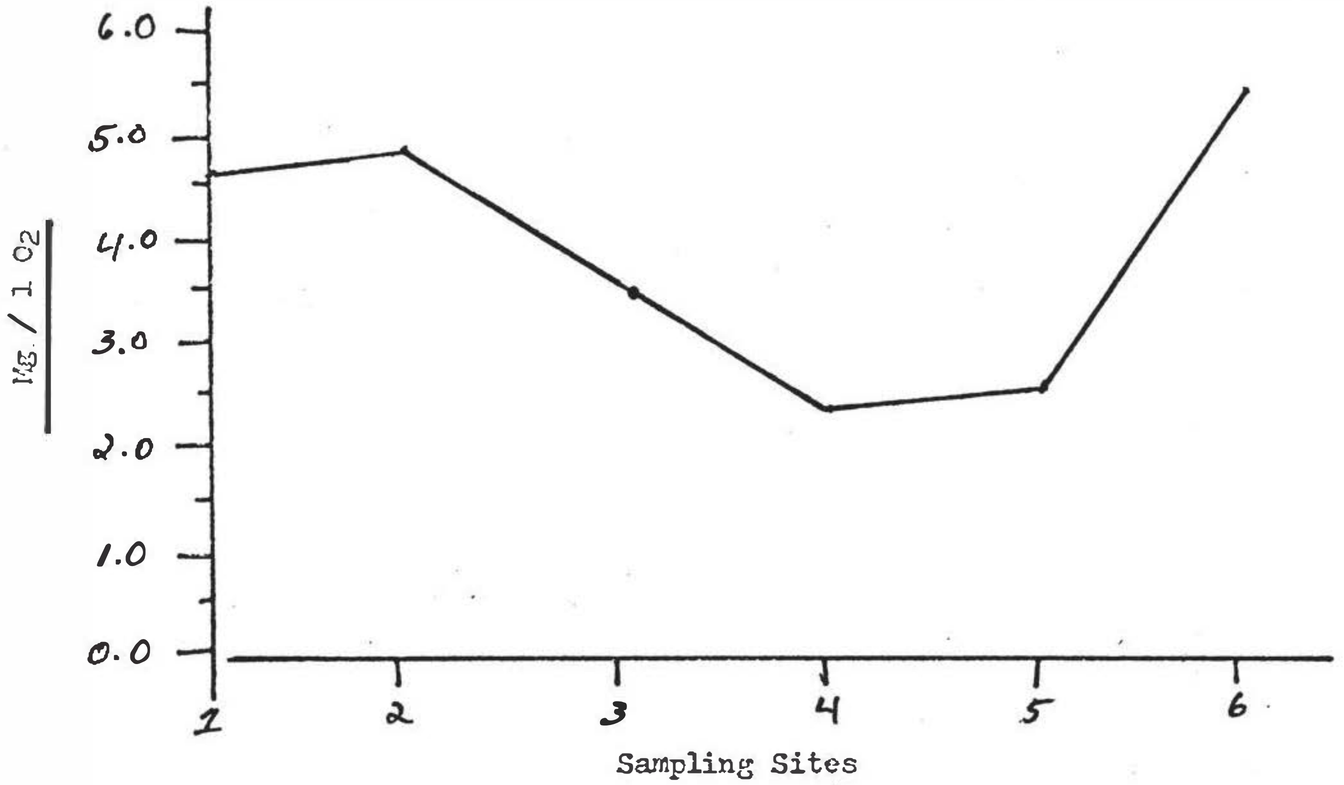
Sampling Sites

MAY BOD.



Sampling Sites

Figure 2


JUNE BOD.

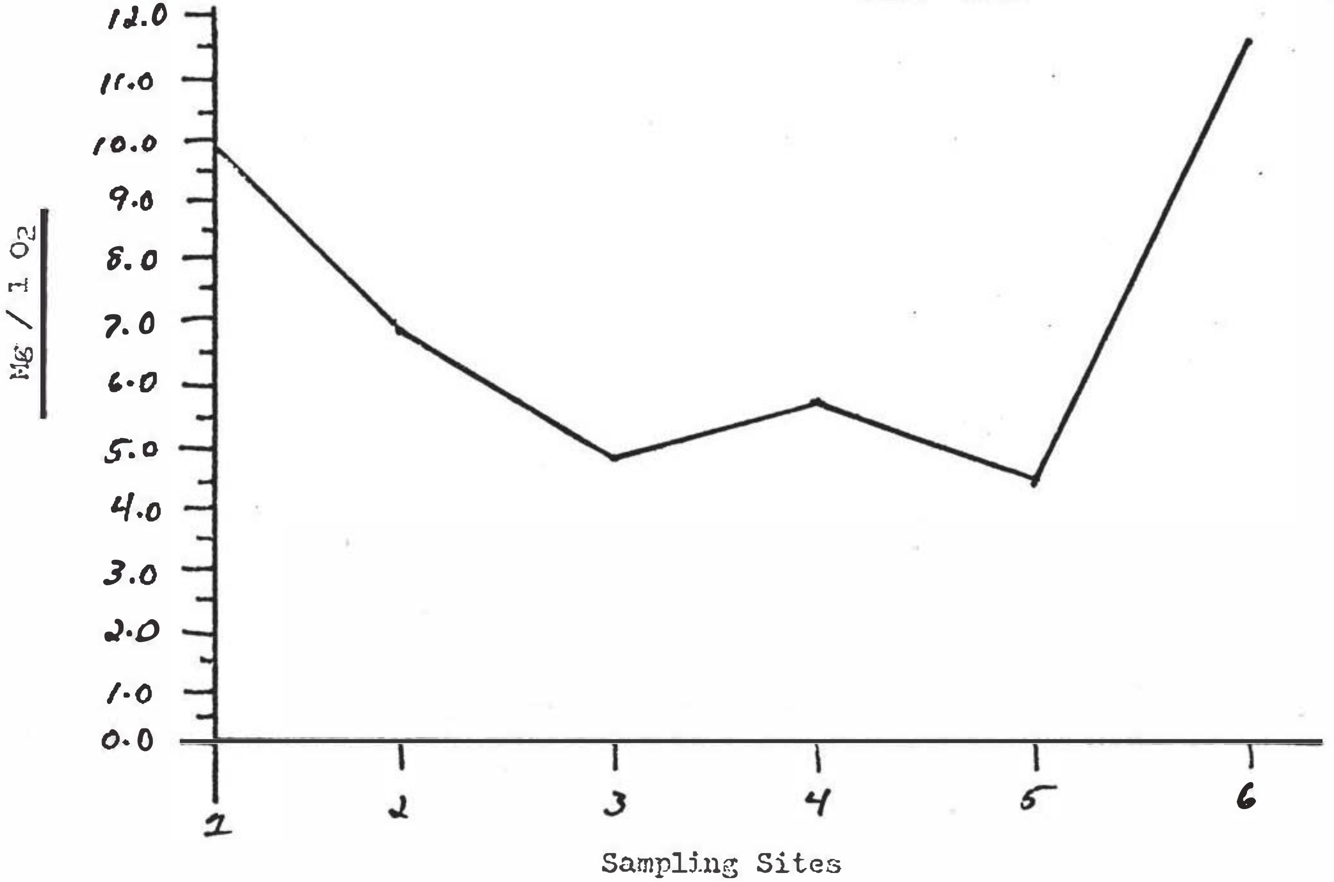
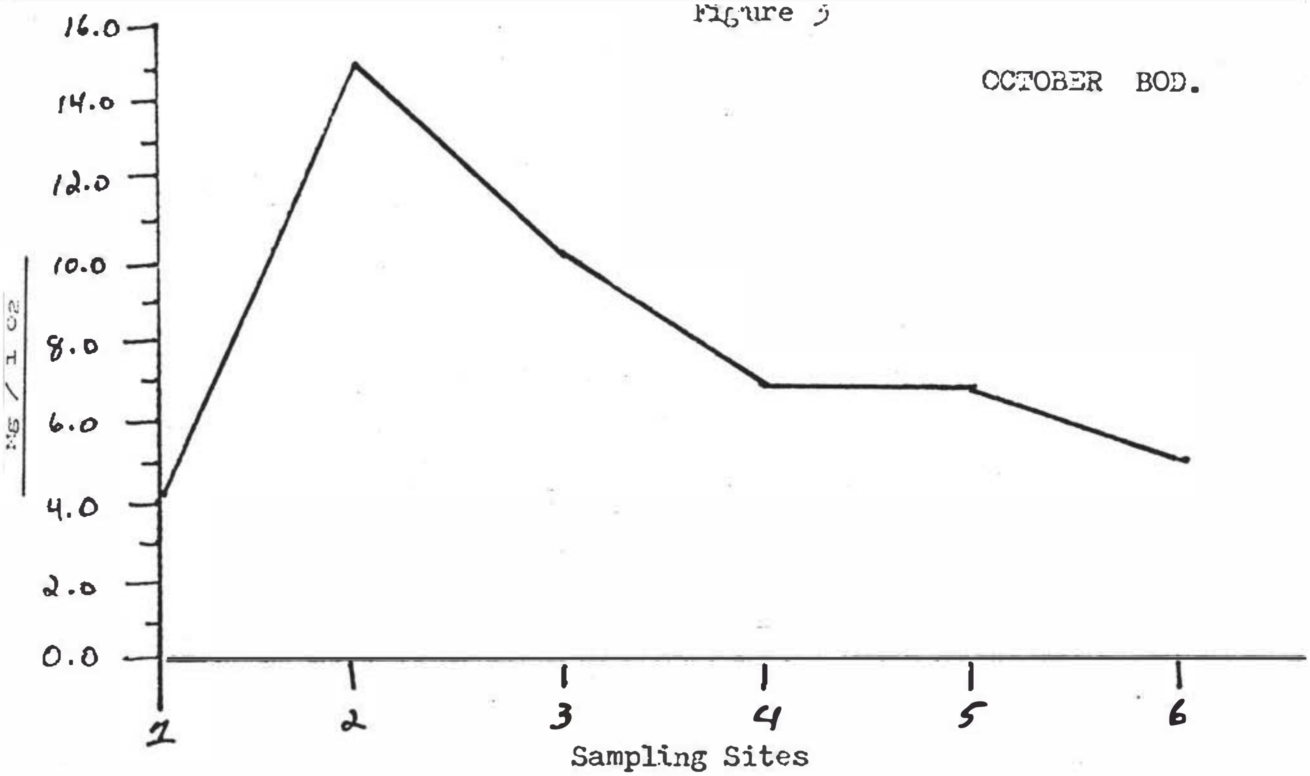

JULY BOD.

Figure 5


OCTOBER BOD.
Mg / l O2
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
1
2
3
4
5
6
Sampling Sites

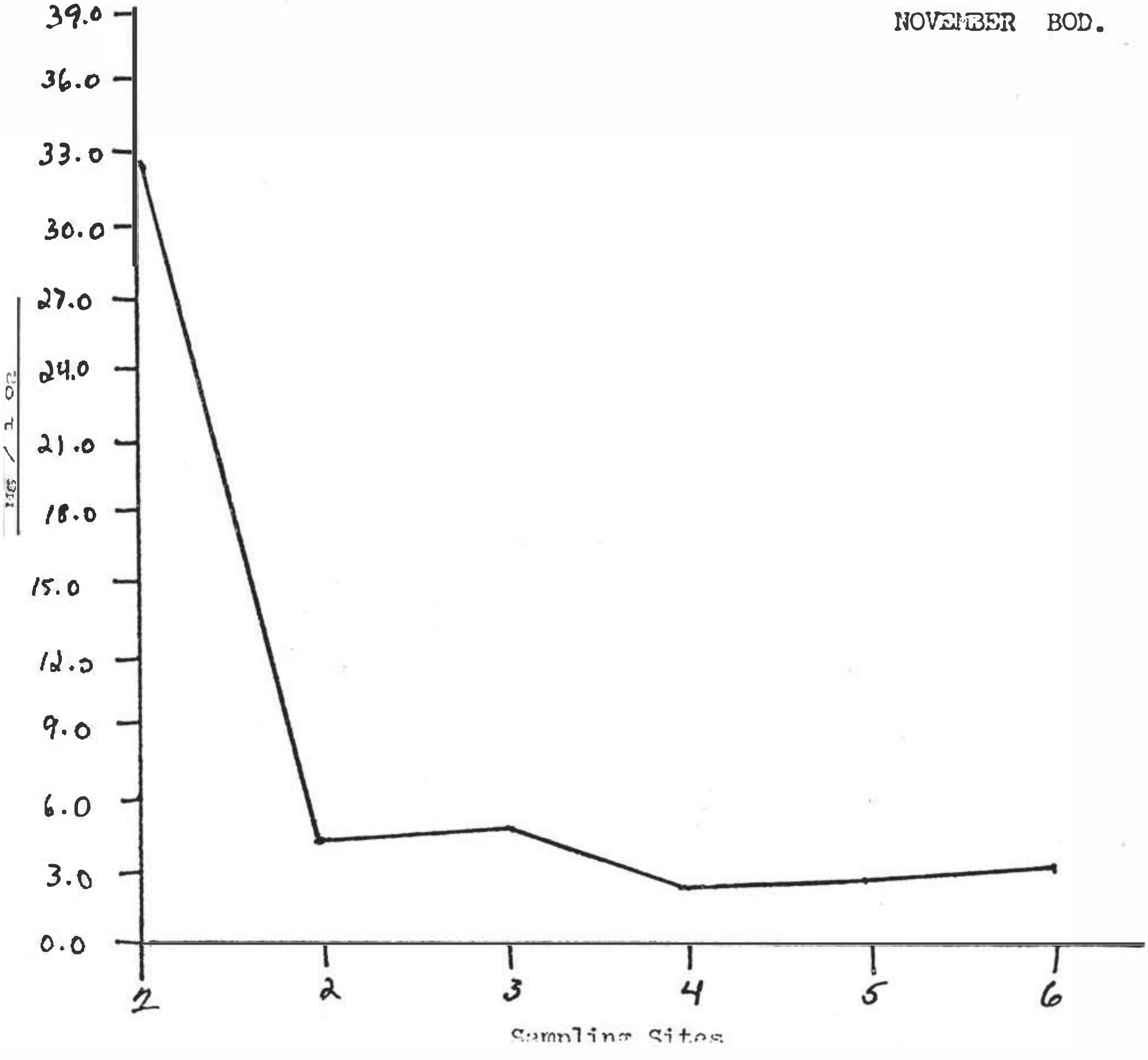
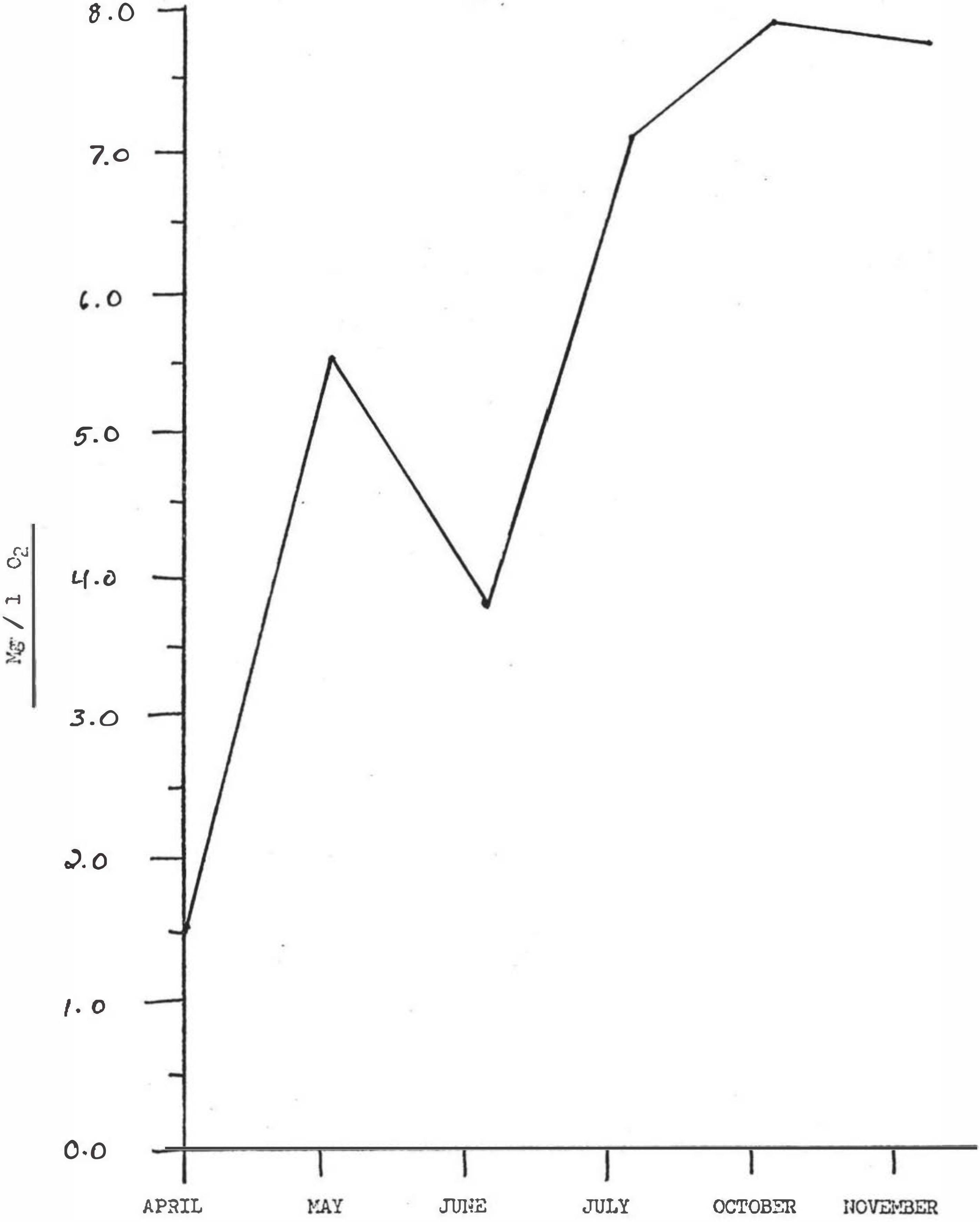
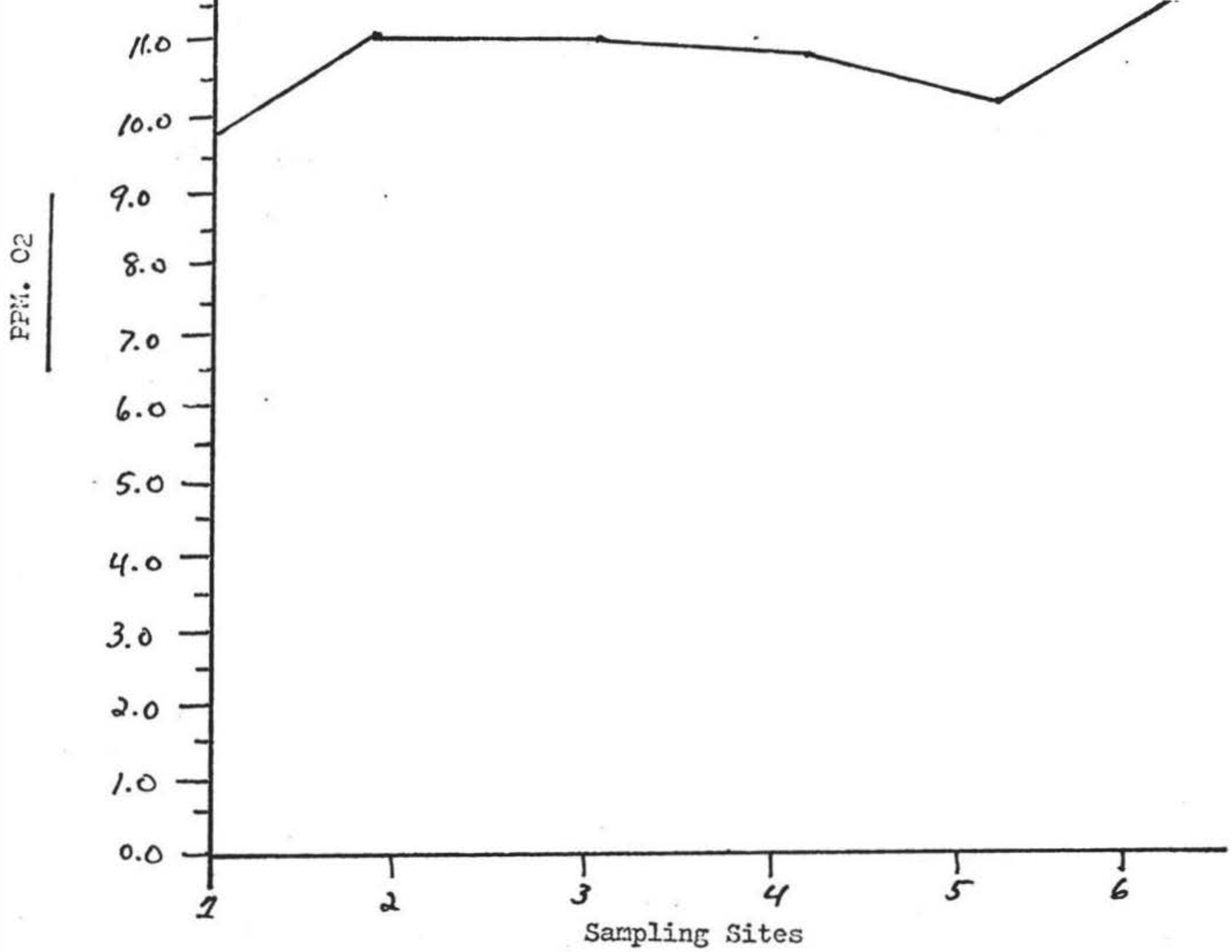

NOVEMBER BOD.
Mg / l O2
39.0
36.0
33.0
30.0
27.0
24.0
21.0
18.0
15.0
12.0
9.0
6.0
3.0
0.0
1
2
3
4
5
6
Sampling Sites

Figure 4



MEAN BOD. / SAMPLING PERIOD


11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
PPM. O2
1
2
3
4
5
6
Sampling Sites

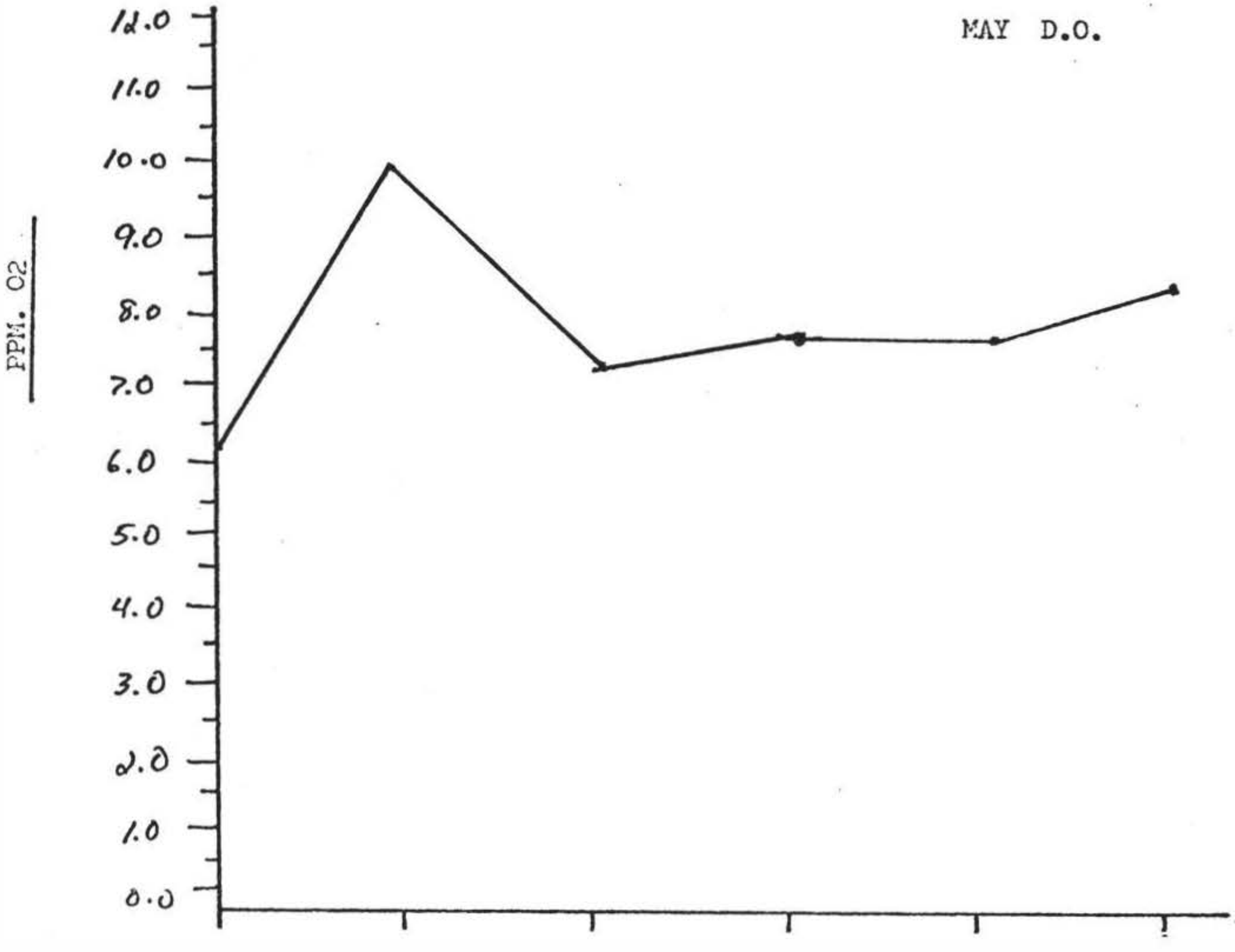
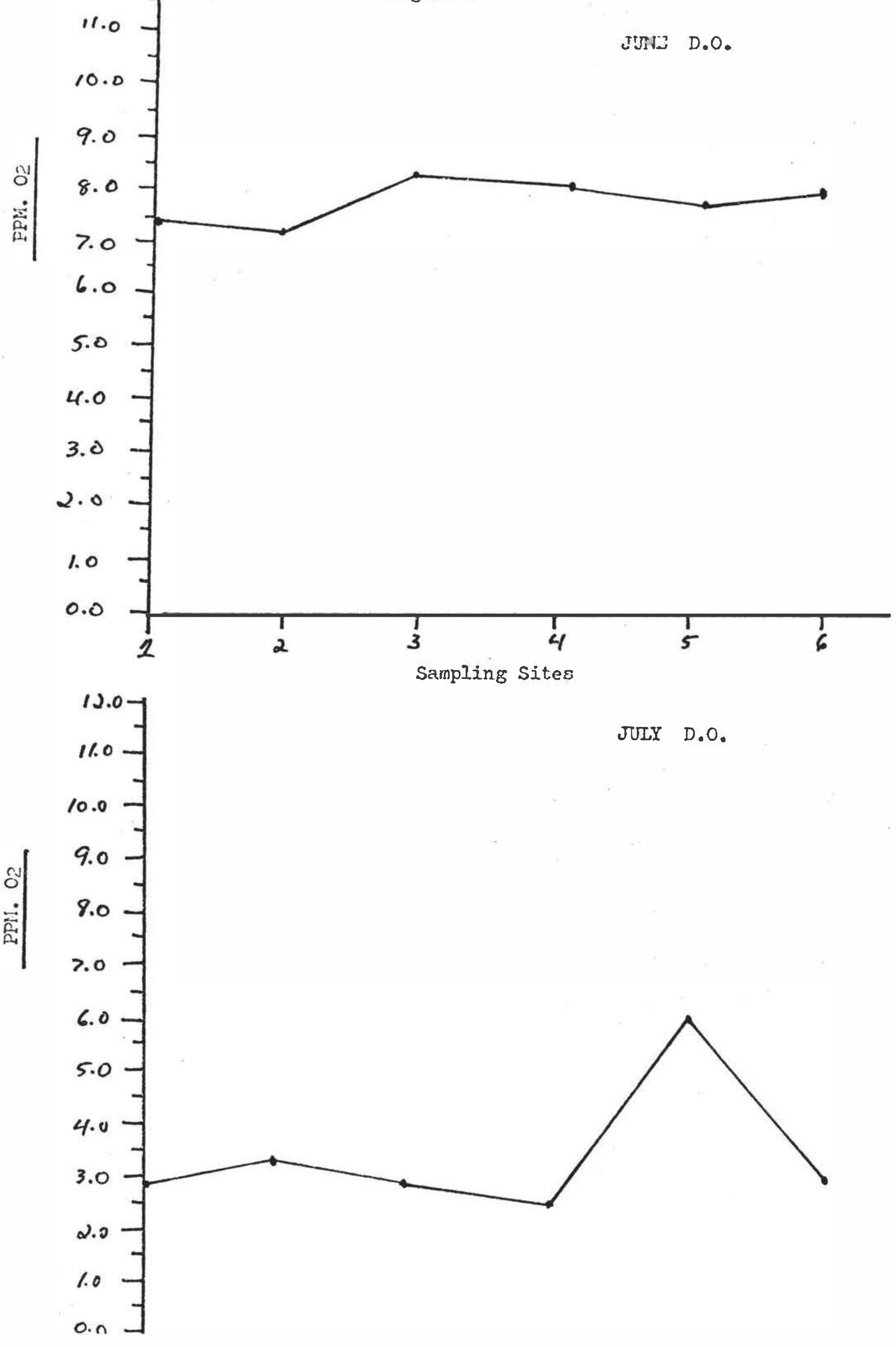
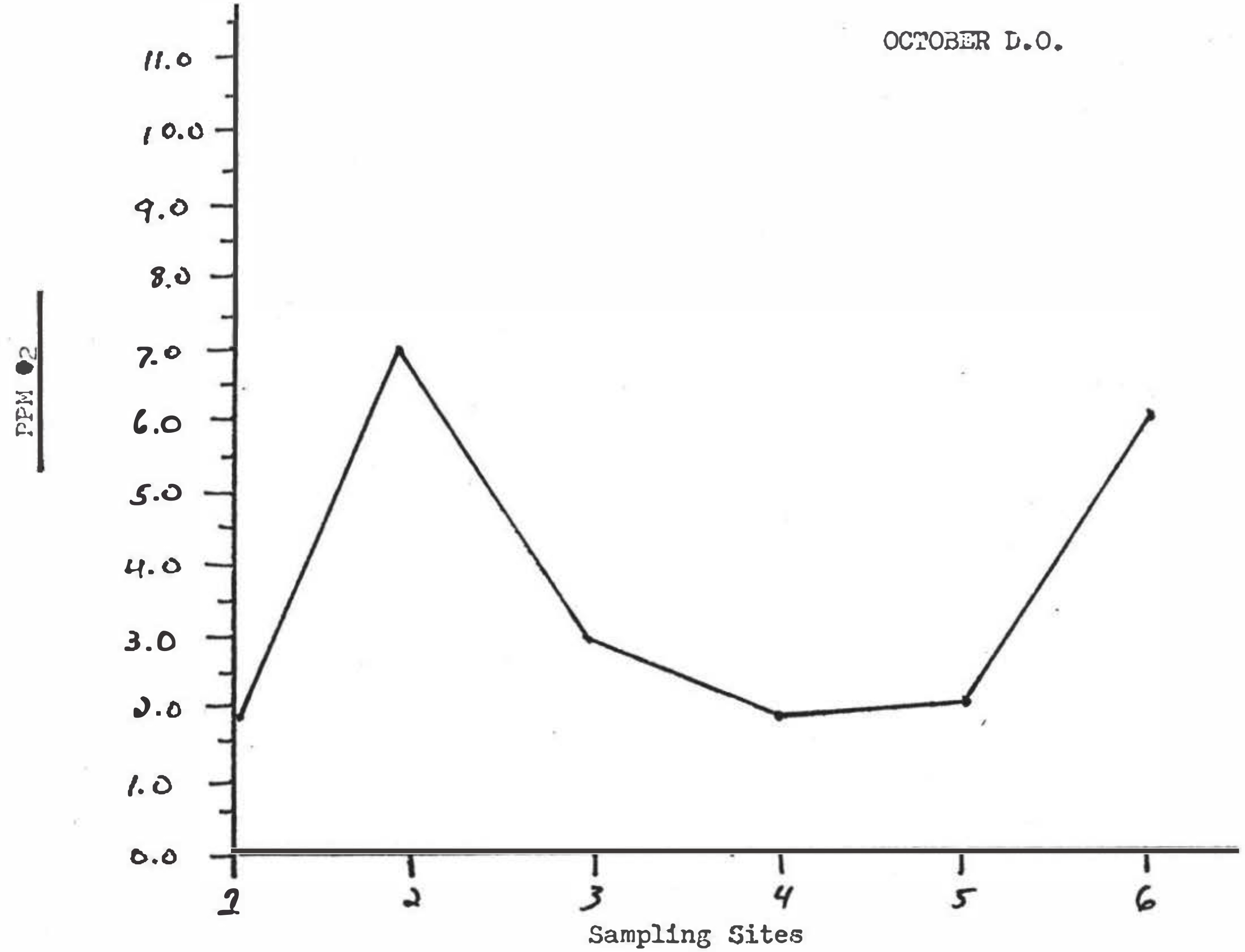

MAY D.O.
12.0
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
PPM. O2

Figure 6


JUNE D.O.
PPM. O2
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
1
2
3
4
5
6
Sampling Sites
JULY D.O.
PPM. O2
12.0
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0


OCTOBER D.O.
PPM O2
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
1
2
3
4
5
6
Sampling Sites

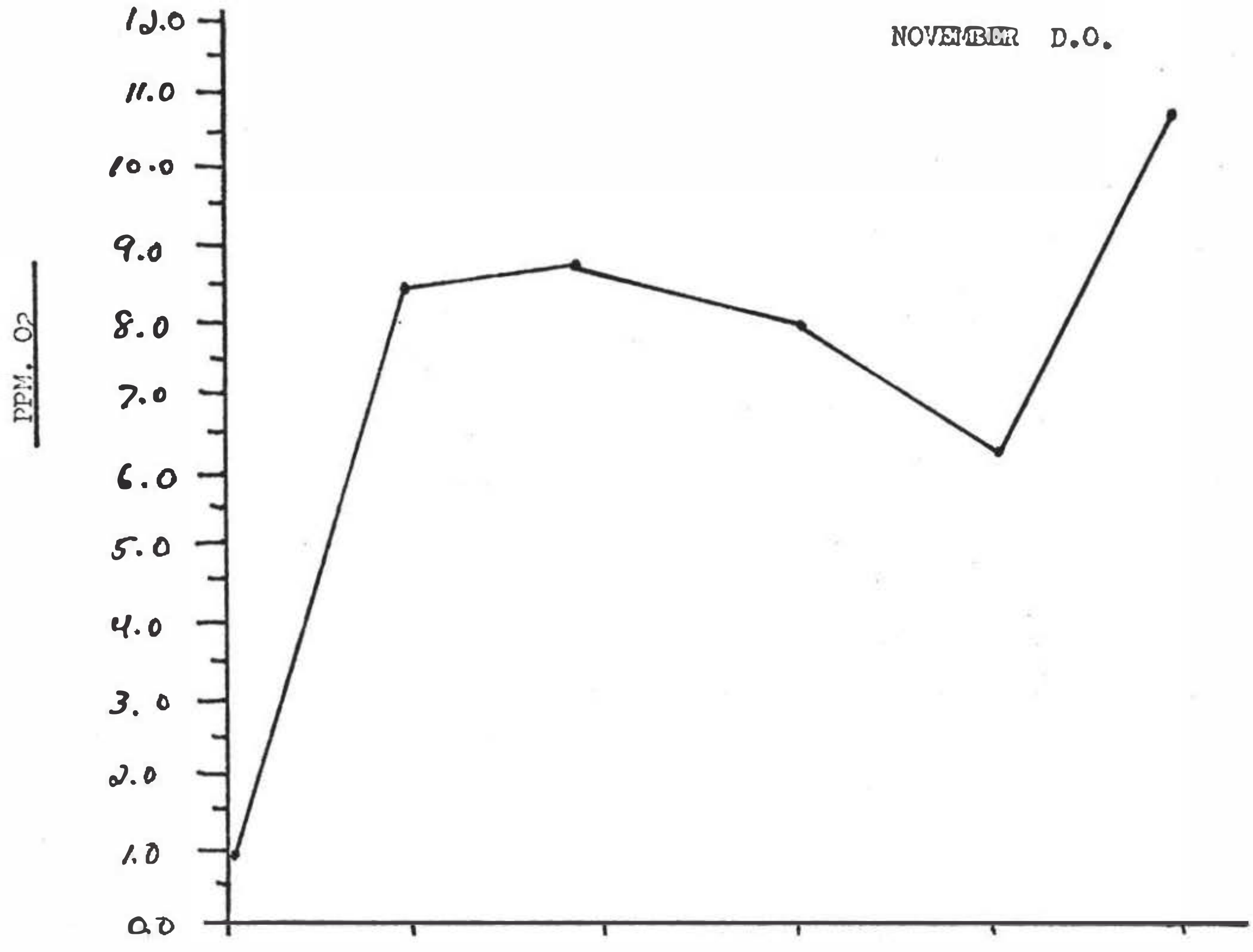
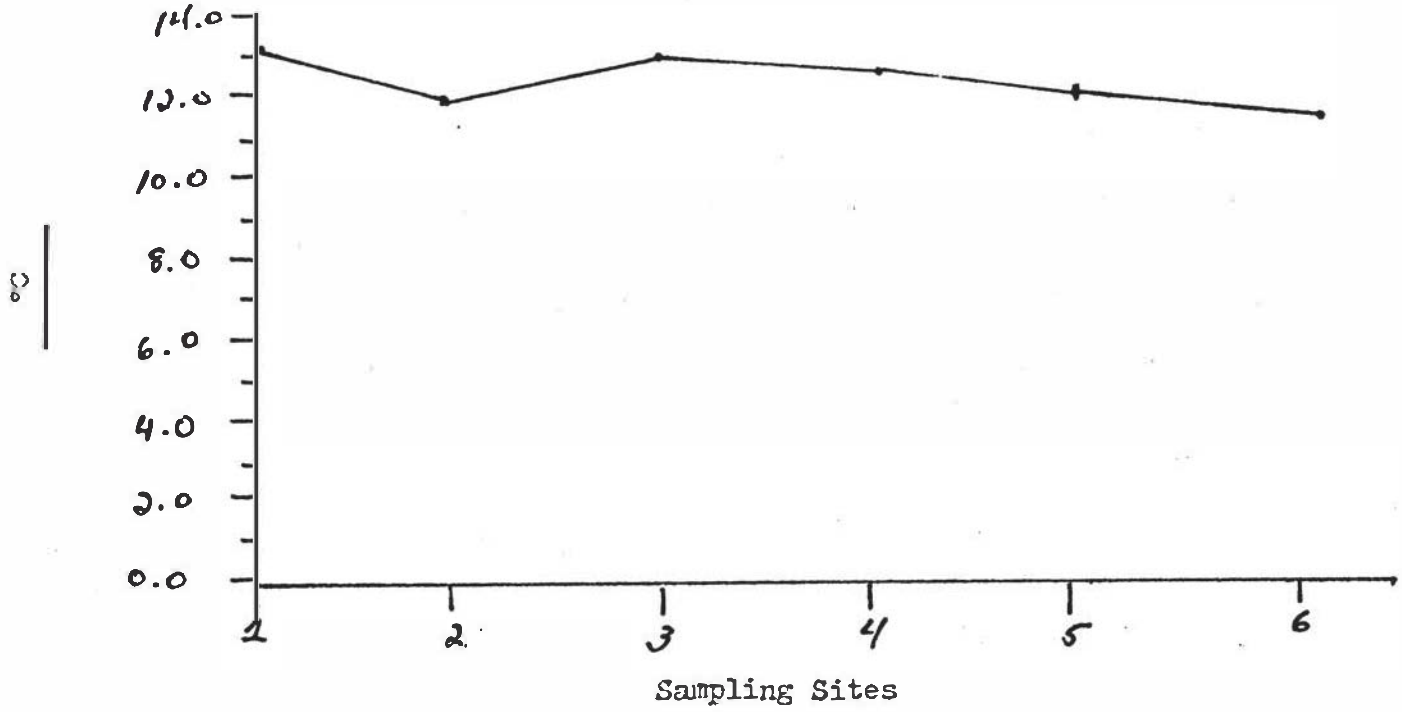

NOVEMBER D.O.
PPM. O2
12.0
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0

Figure 8

APRIL TEMPERATURES



MAY TEMPERATURES

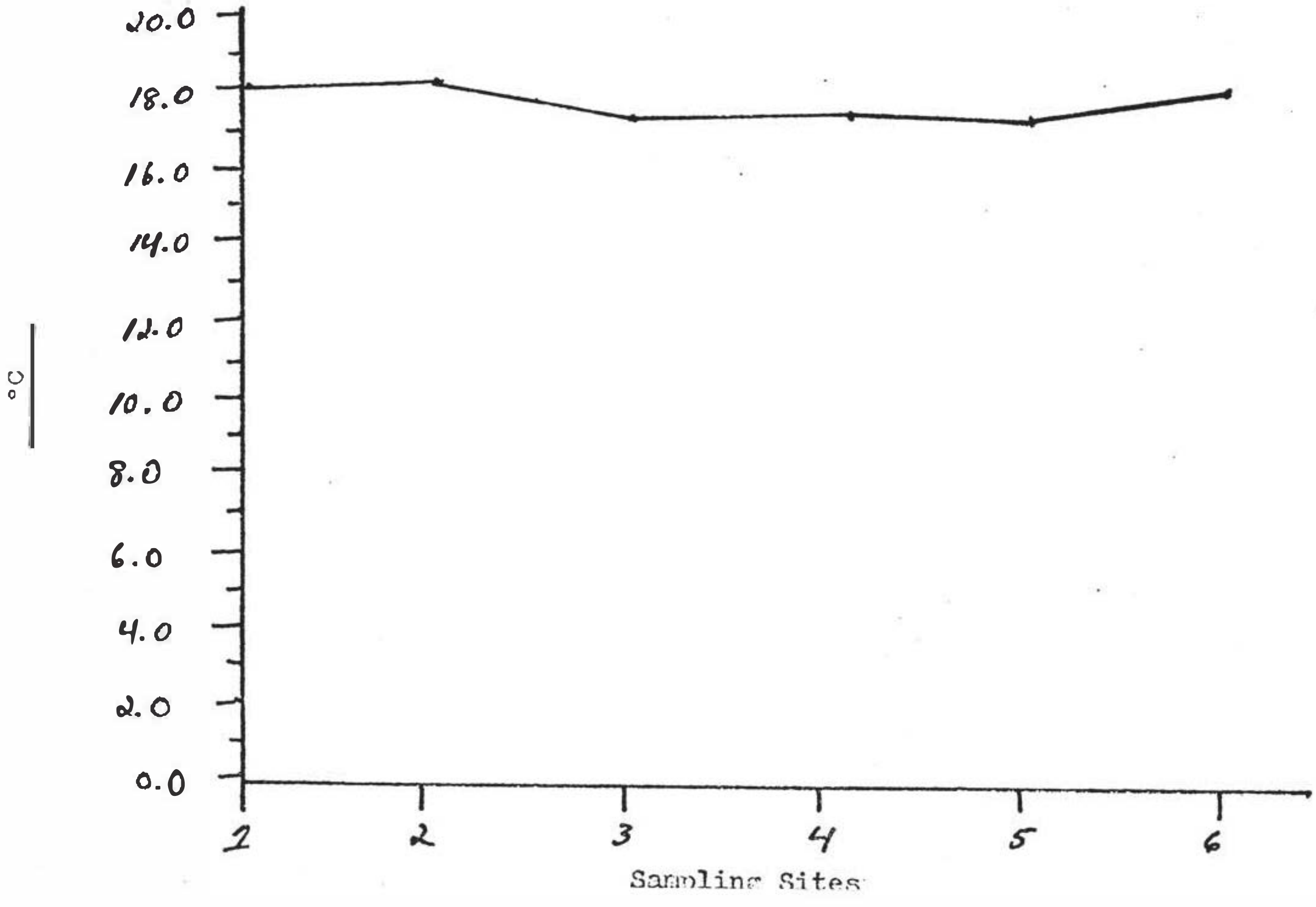


Figure 9

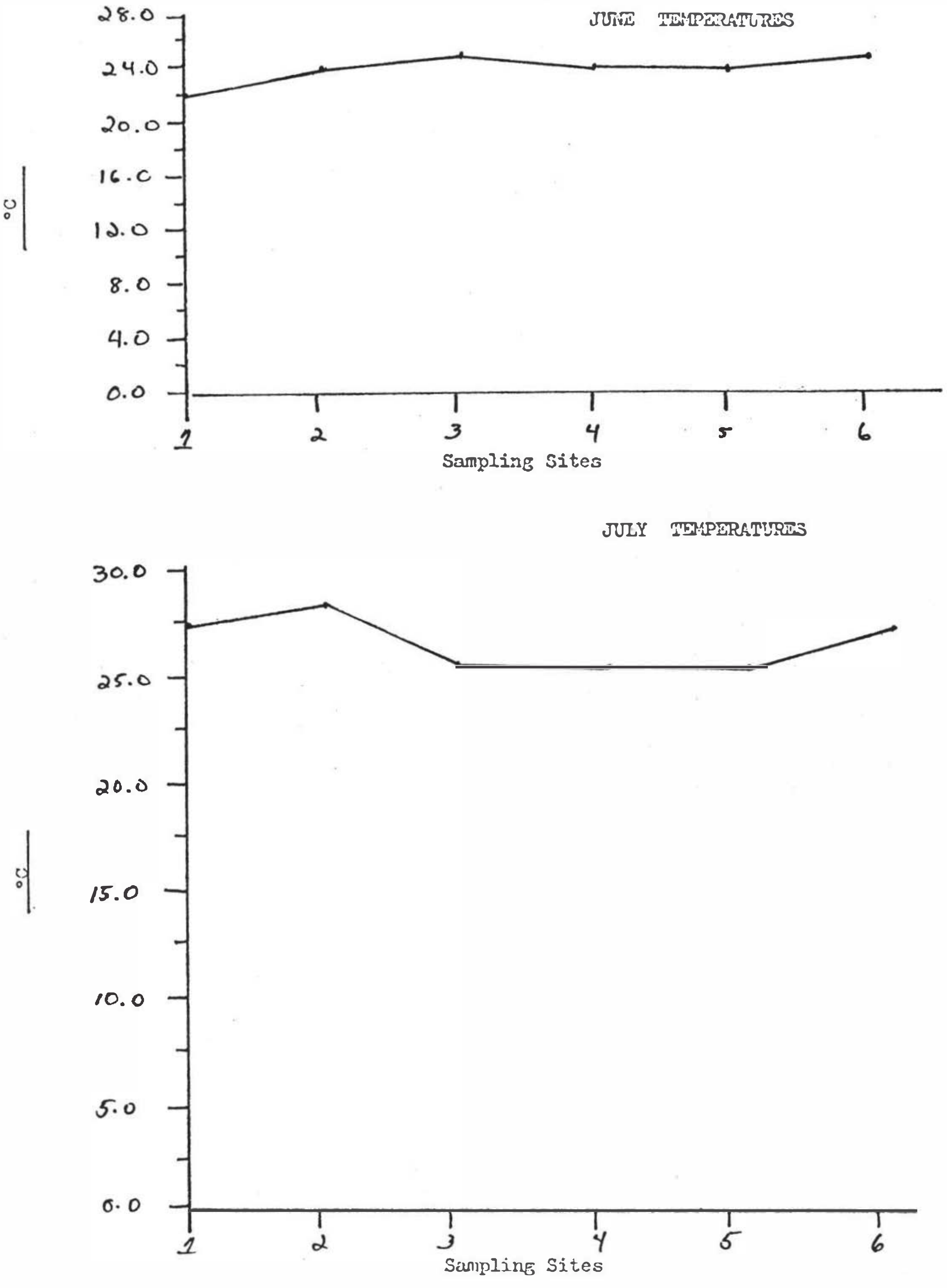
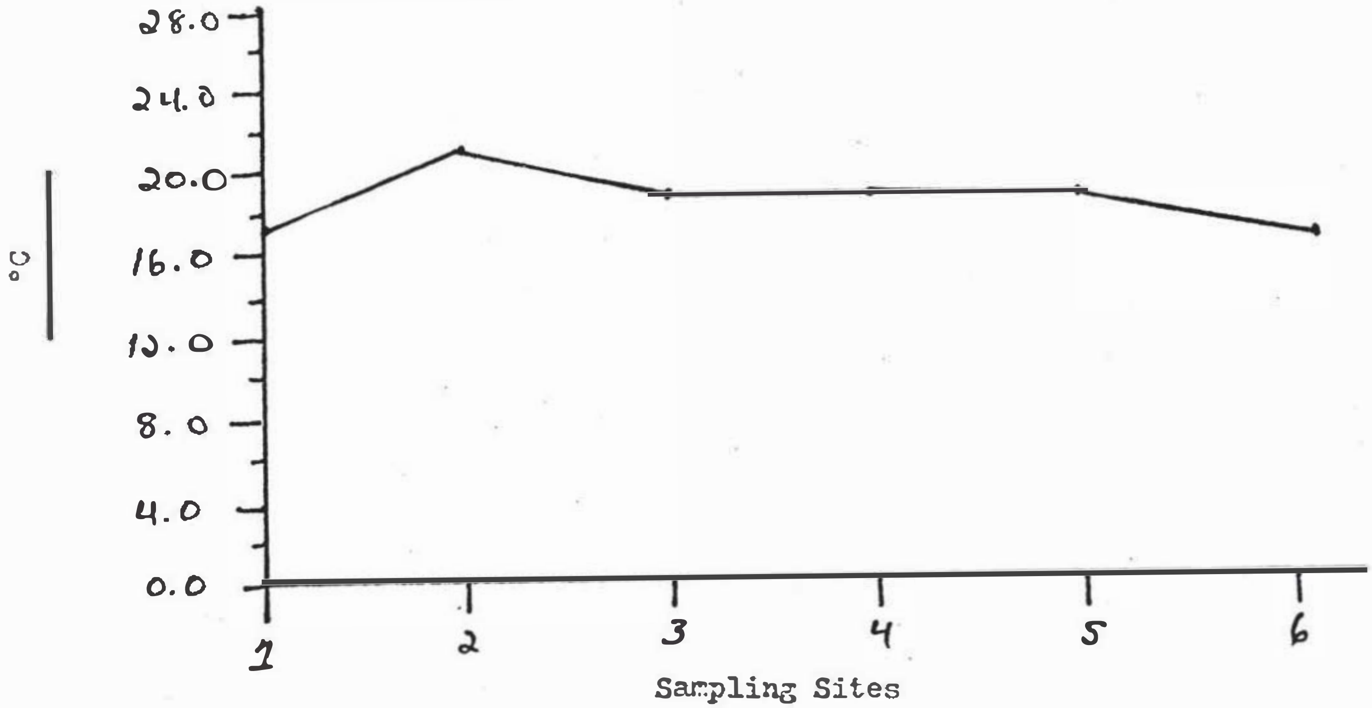

JUNE TEMPERATURES
28.0
24.0
20.0
16.0
12.0
8.0
4.0
0.0
°C
1
2
3
4
5
6
Sampling Sites
JULY TEMPERATURES
30.0
25.0
20.0
15.0
10.0
5.0
0.0
°C
1
2
3
4
5
6
Sampling Sites

Figure 10

OCTOBER TEMPERATURES



NOVEMBER TEMPERATURES

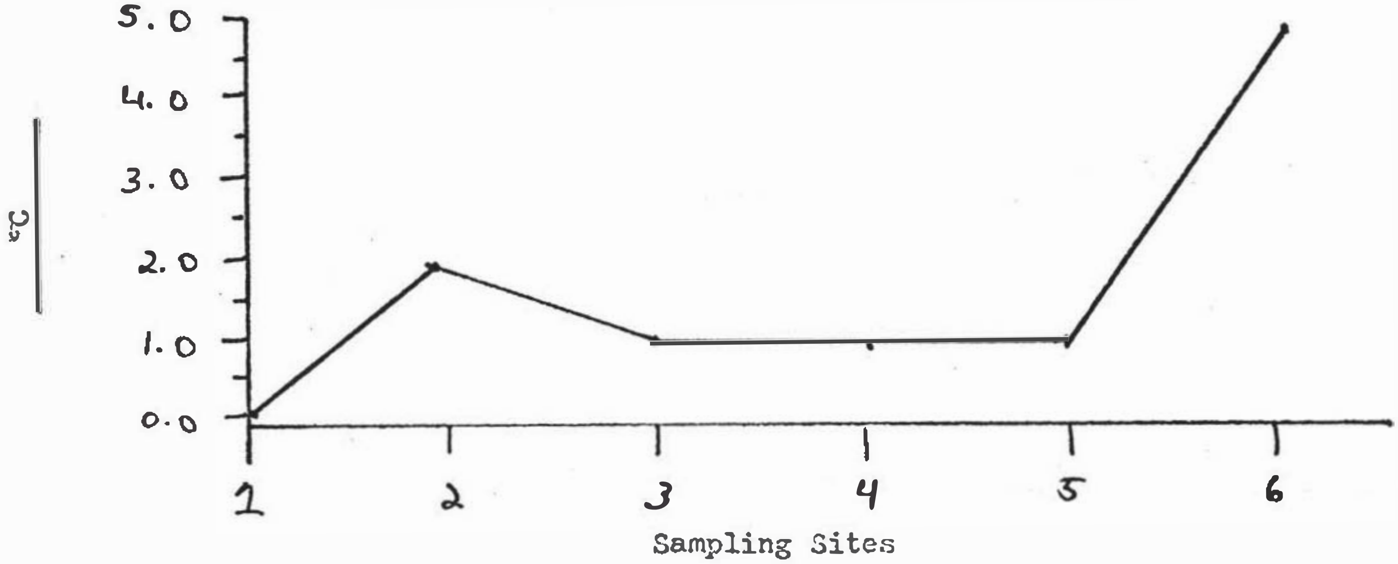
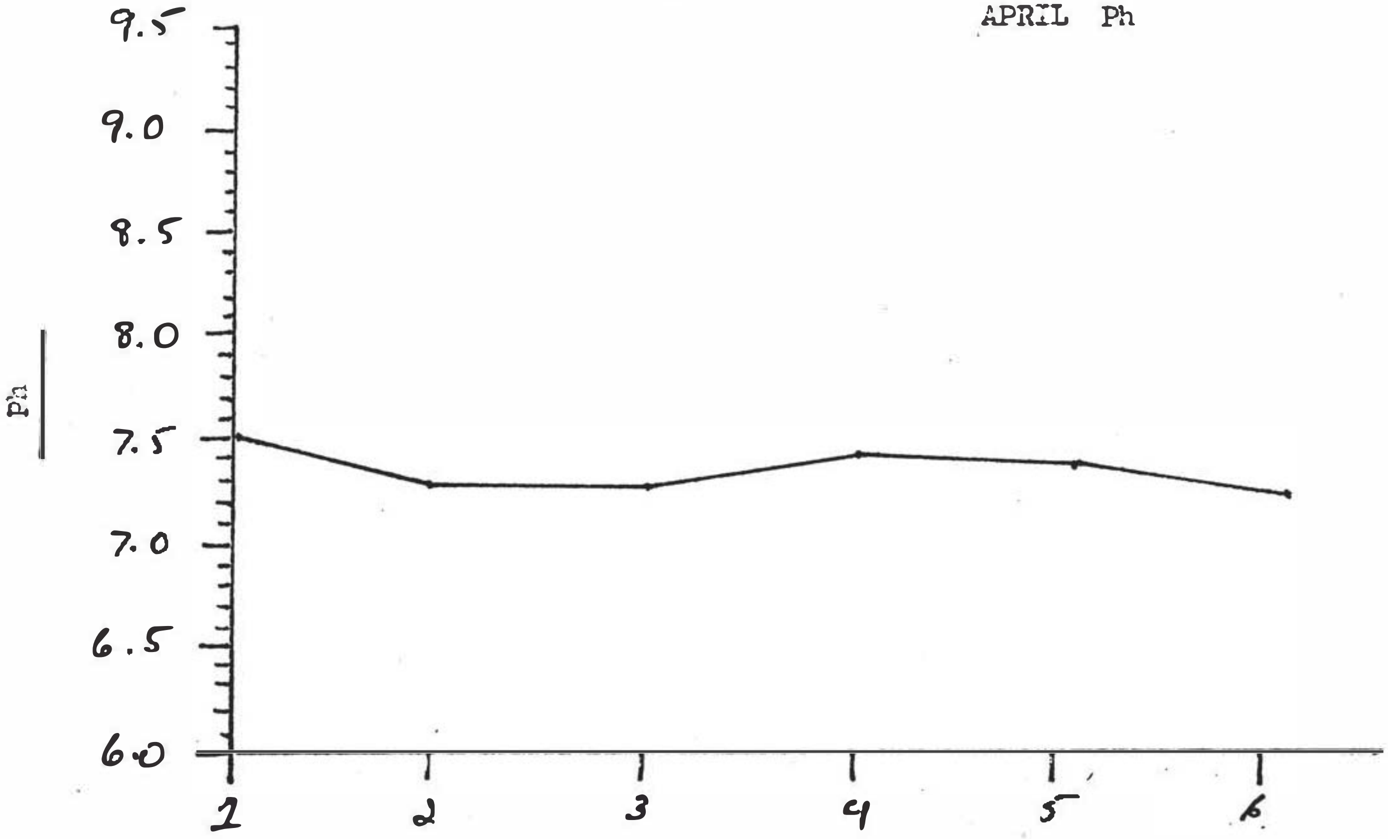
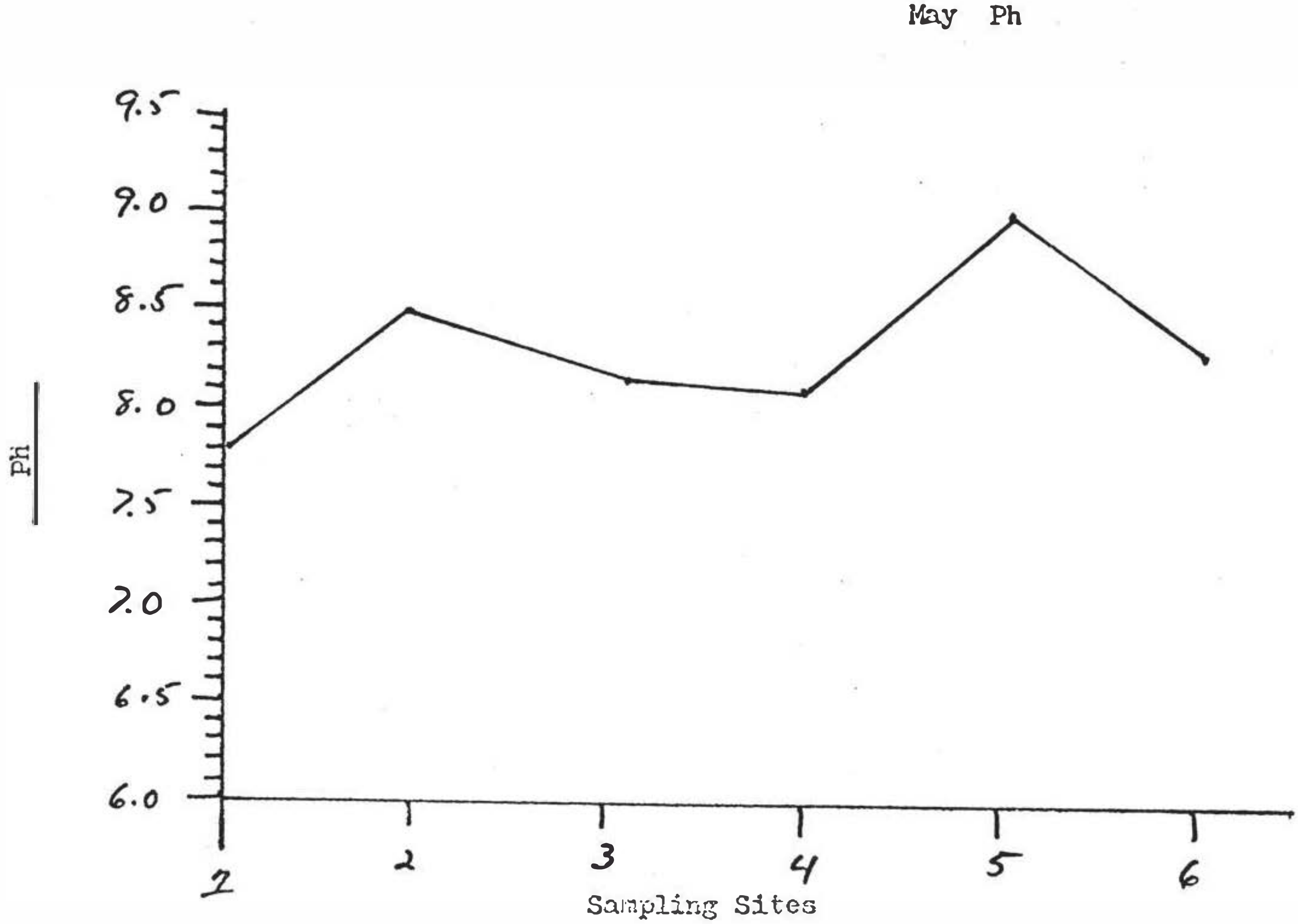


Figure 11

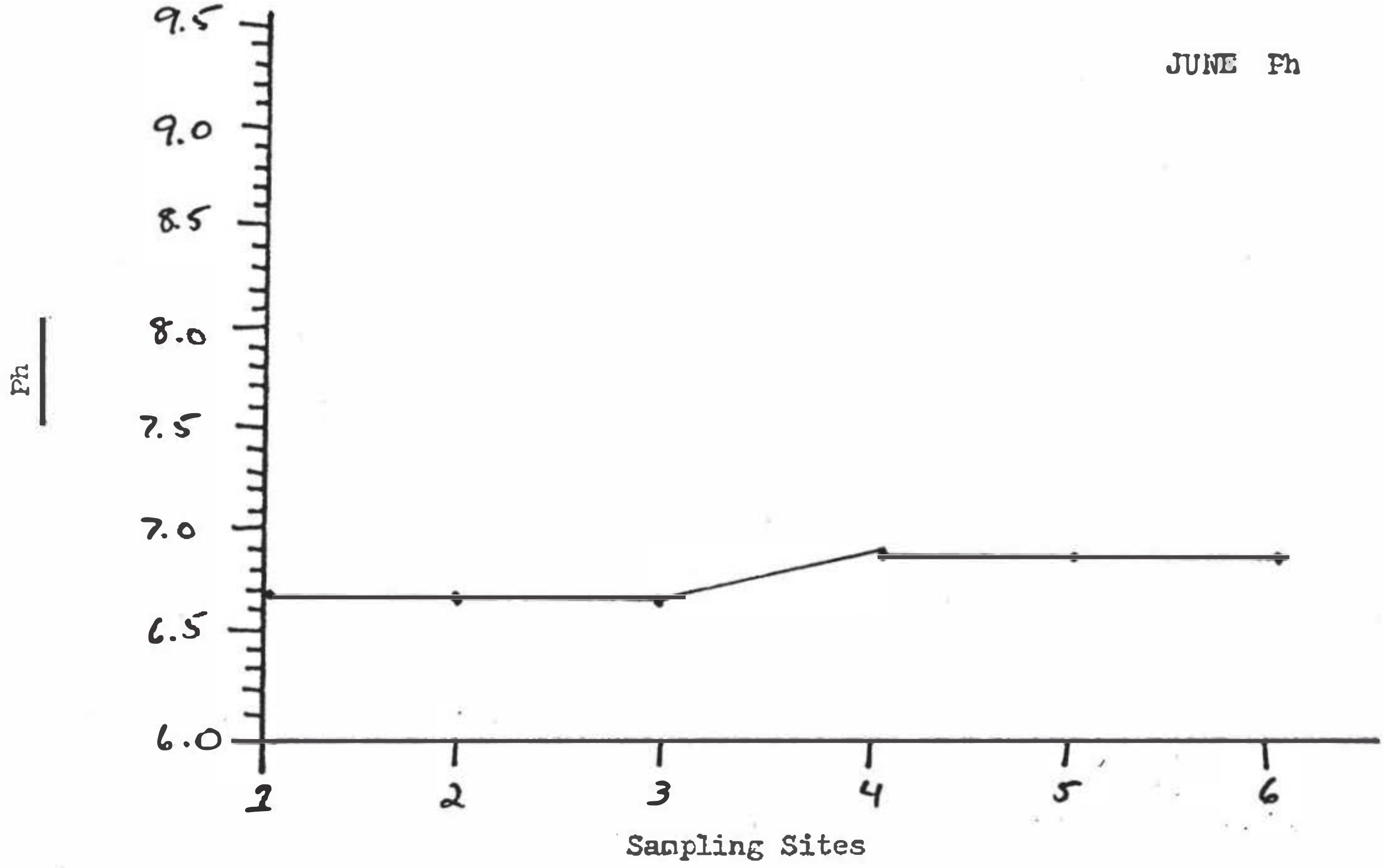


Sampling Sites



Sampling Sites

Figure 12


JUNE Ph
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
Ph
1
2
3
4
5
6
Sampling Sites

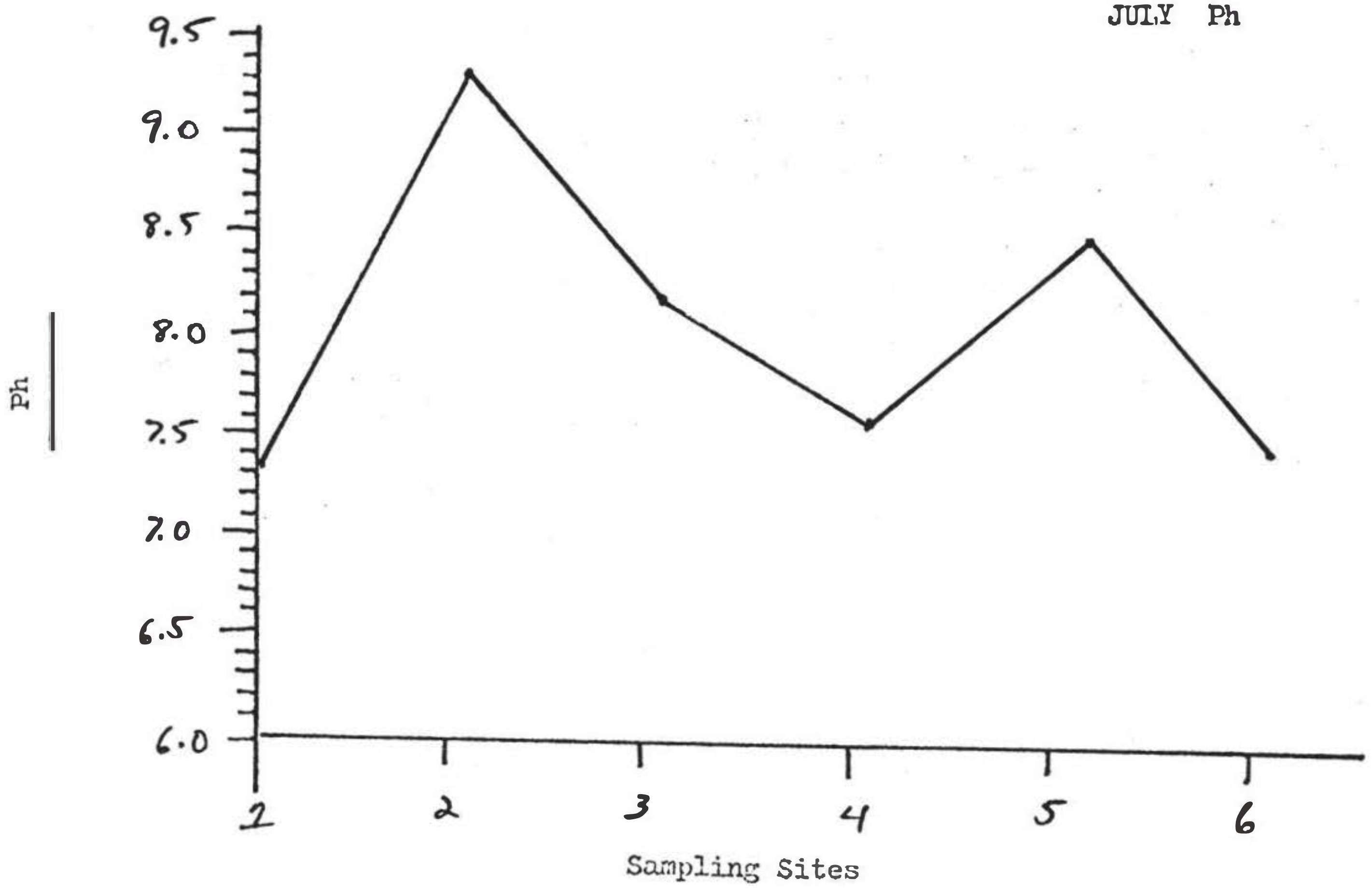
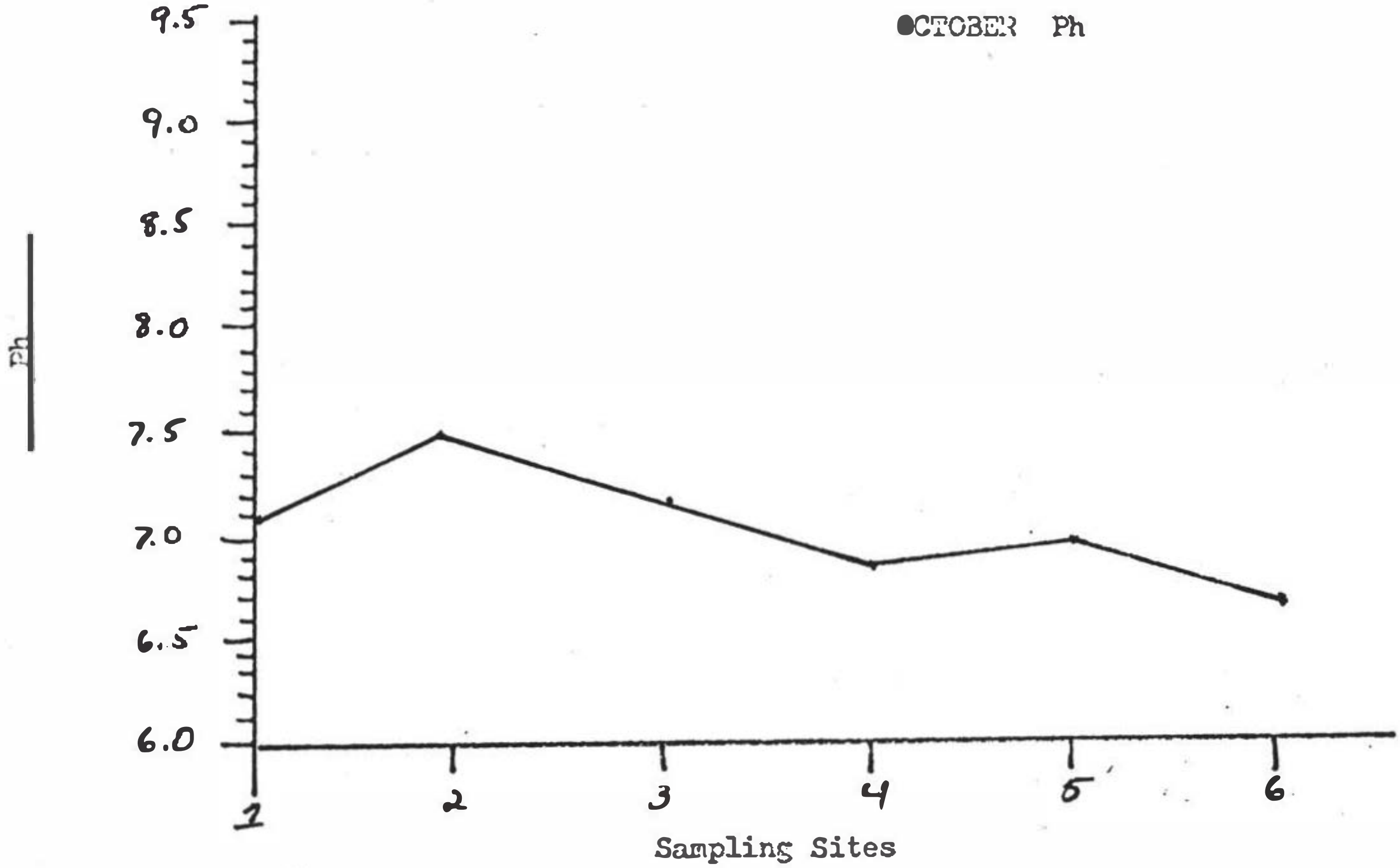

JULY Ph
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
Ph
1
2
3
4
5
6
Sampling Sites

Figure 13


OCTOBER Ph

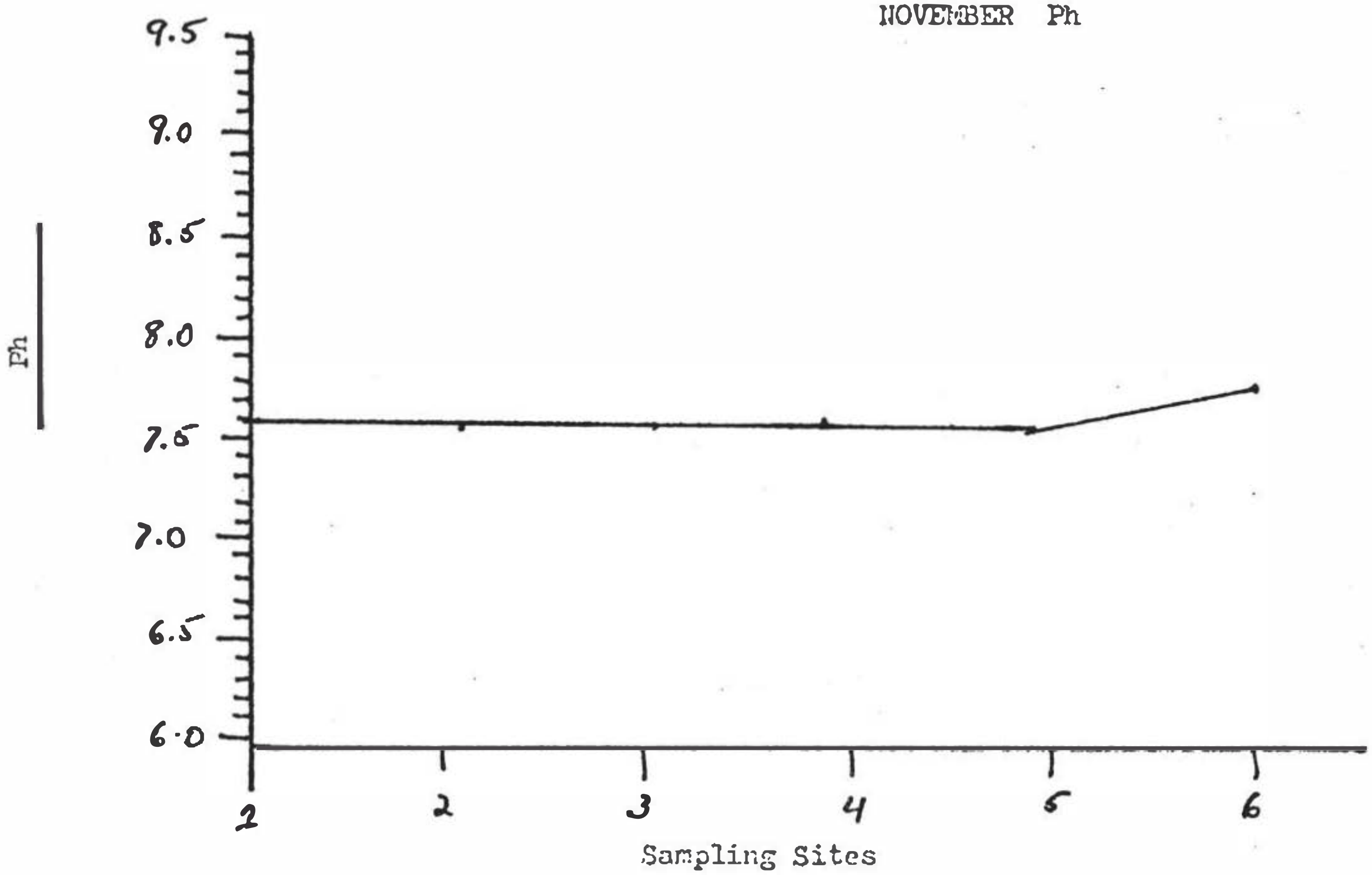
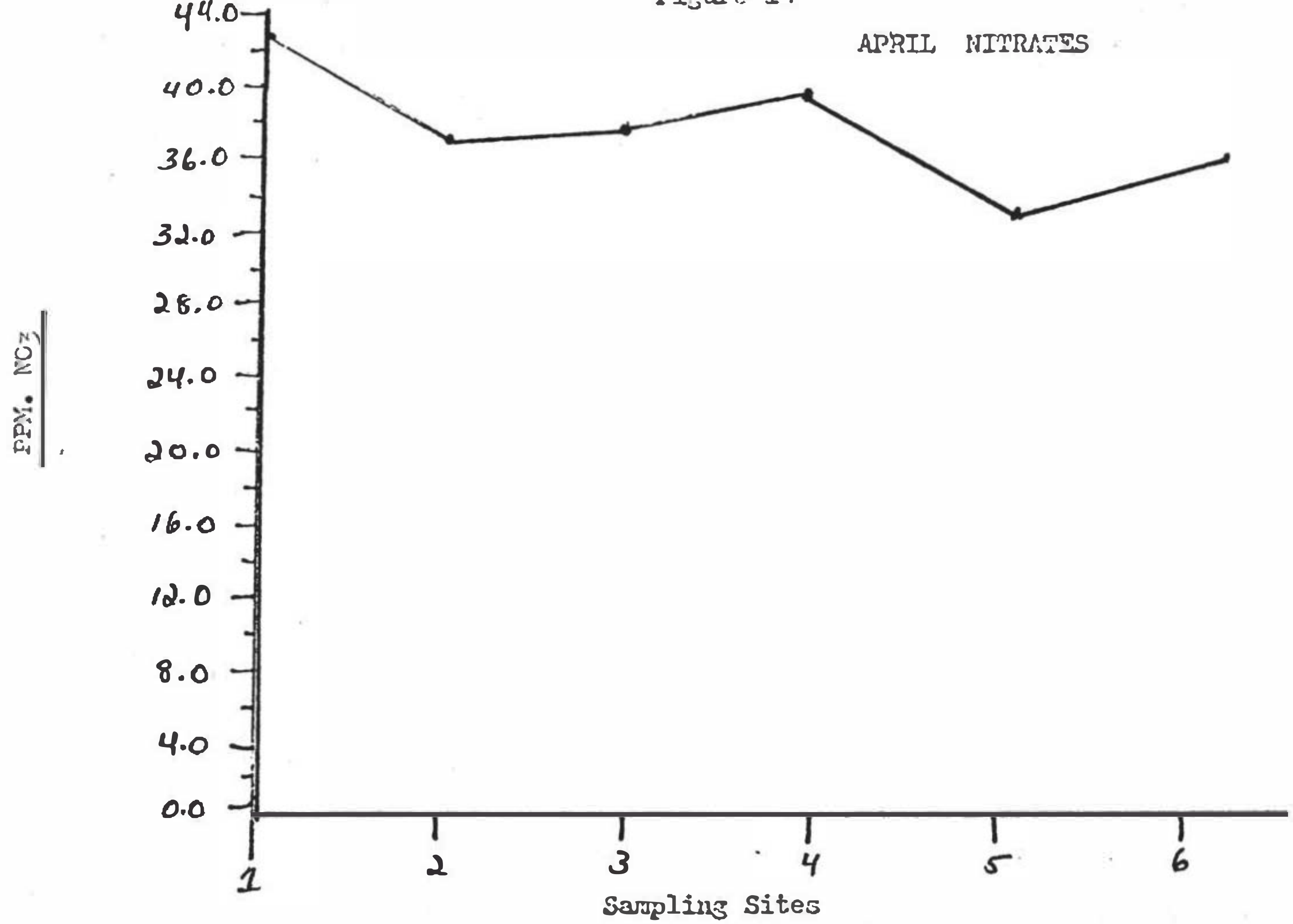

NOVEMBER Ph

Figure 14


APRIL NITRATES
PPM. NO_3
44.0
40.0
36.0
32.0
28.0
24.0
20.0
16.0
12.0
8.0
4.0
0.0
1
2
3
4
5
6
Sampling Sites

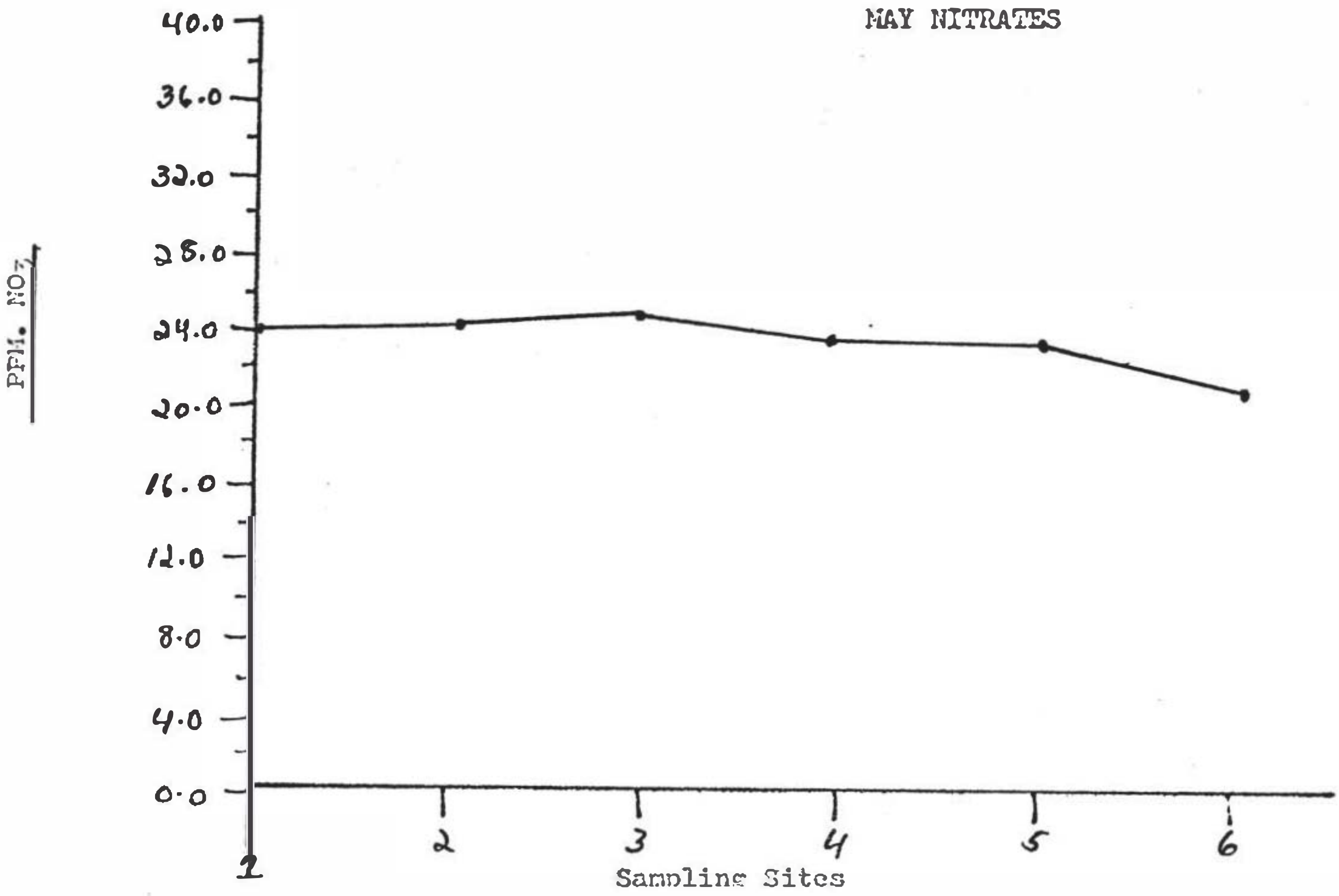
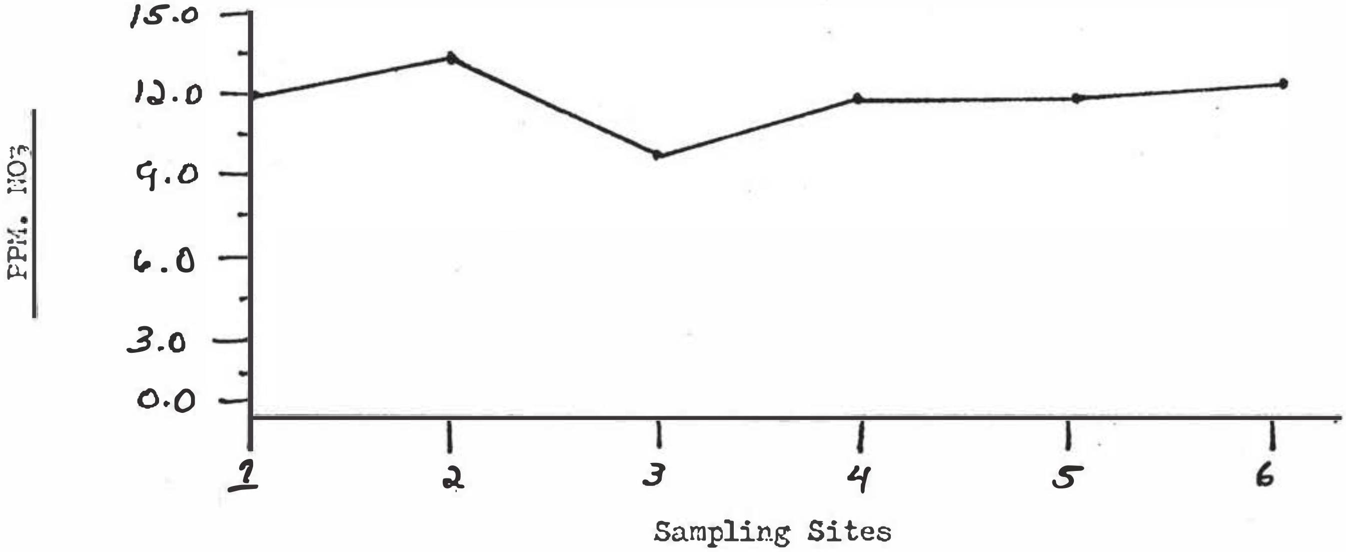

MAY NITRATES
PPM. NO_3
40.0
36.0
32.0
28.0
24.0
20.0
16.0
12.0
8.0
4.0
0.0
1
2
3
4
5
6
Sampling Sites

Figure 15


JUNE NITRATES

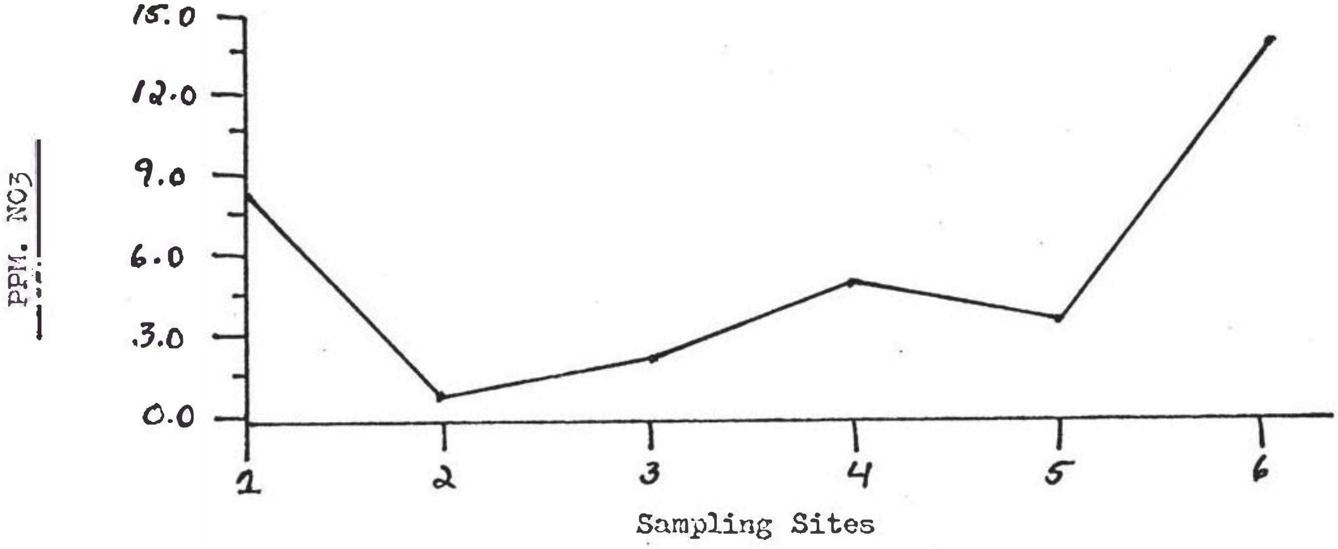
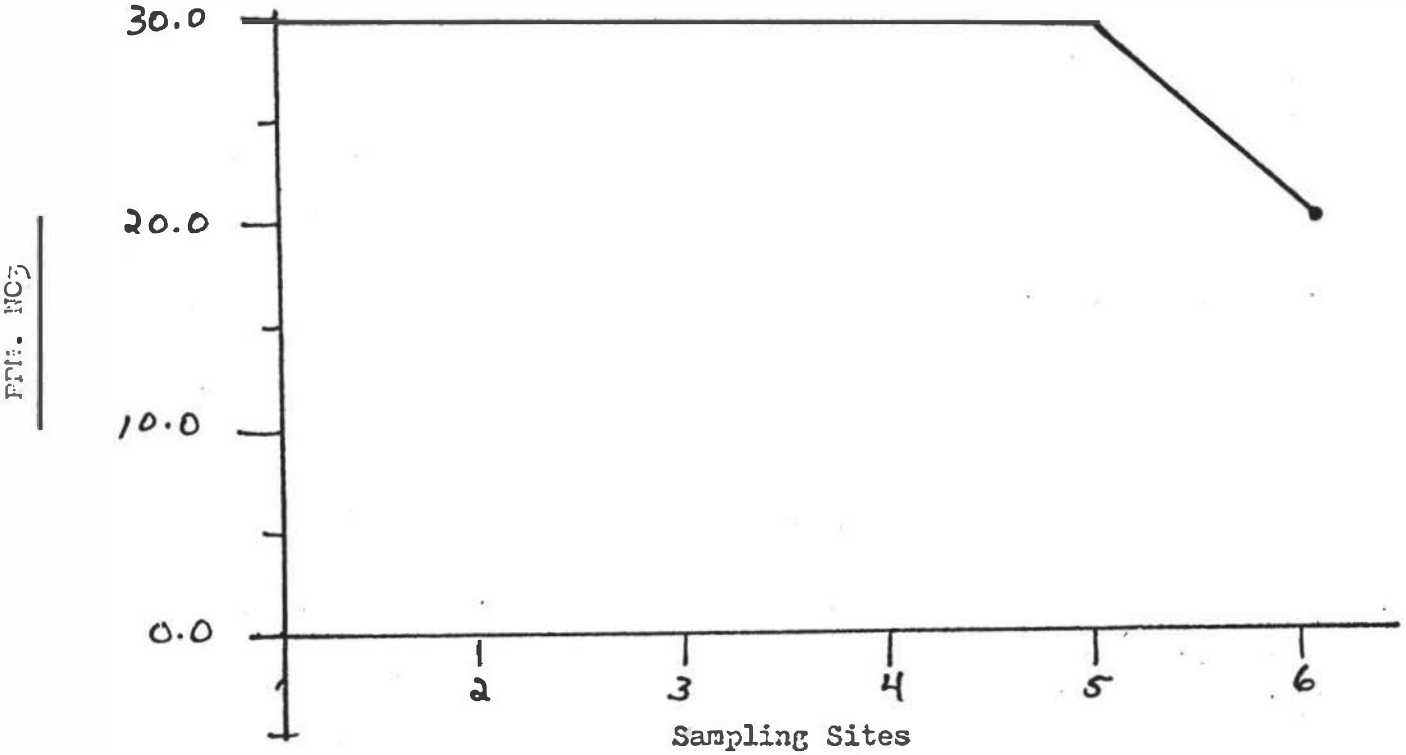

JULY NITRATES

Figure 16

OCTOBER NITRATES



NOVEMBER NITRATES

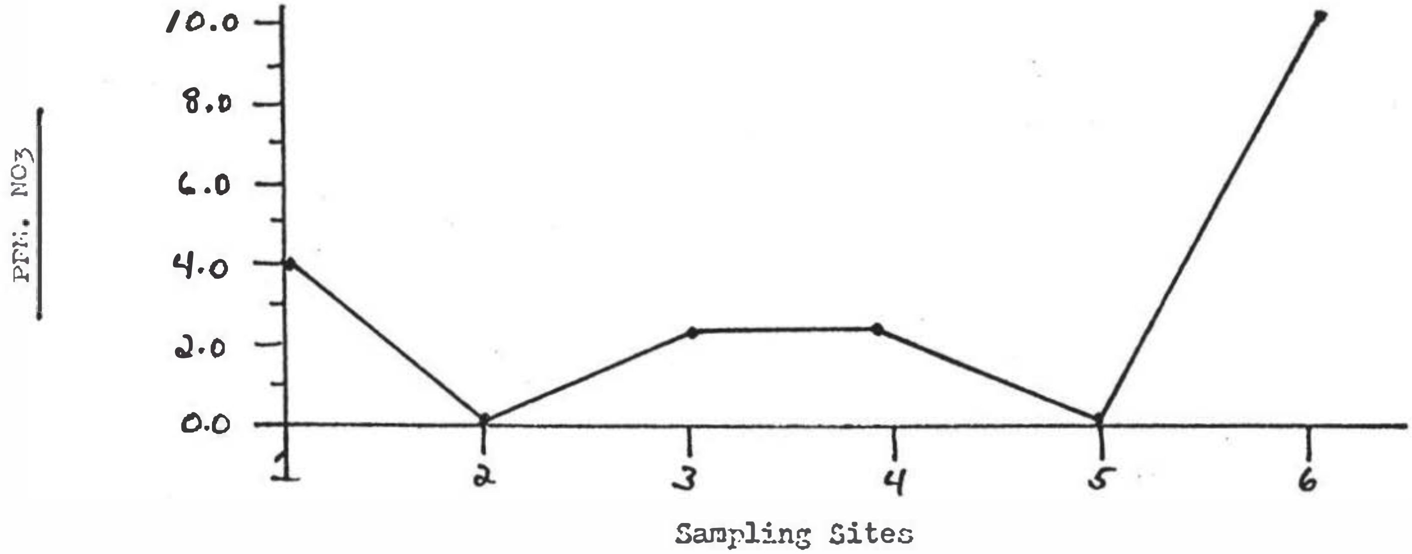
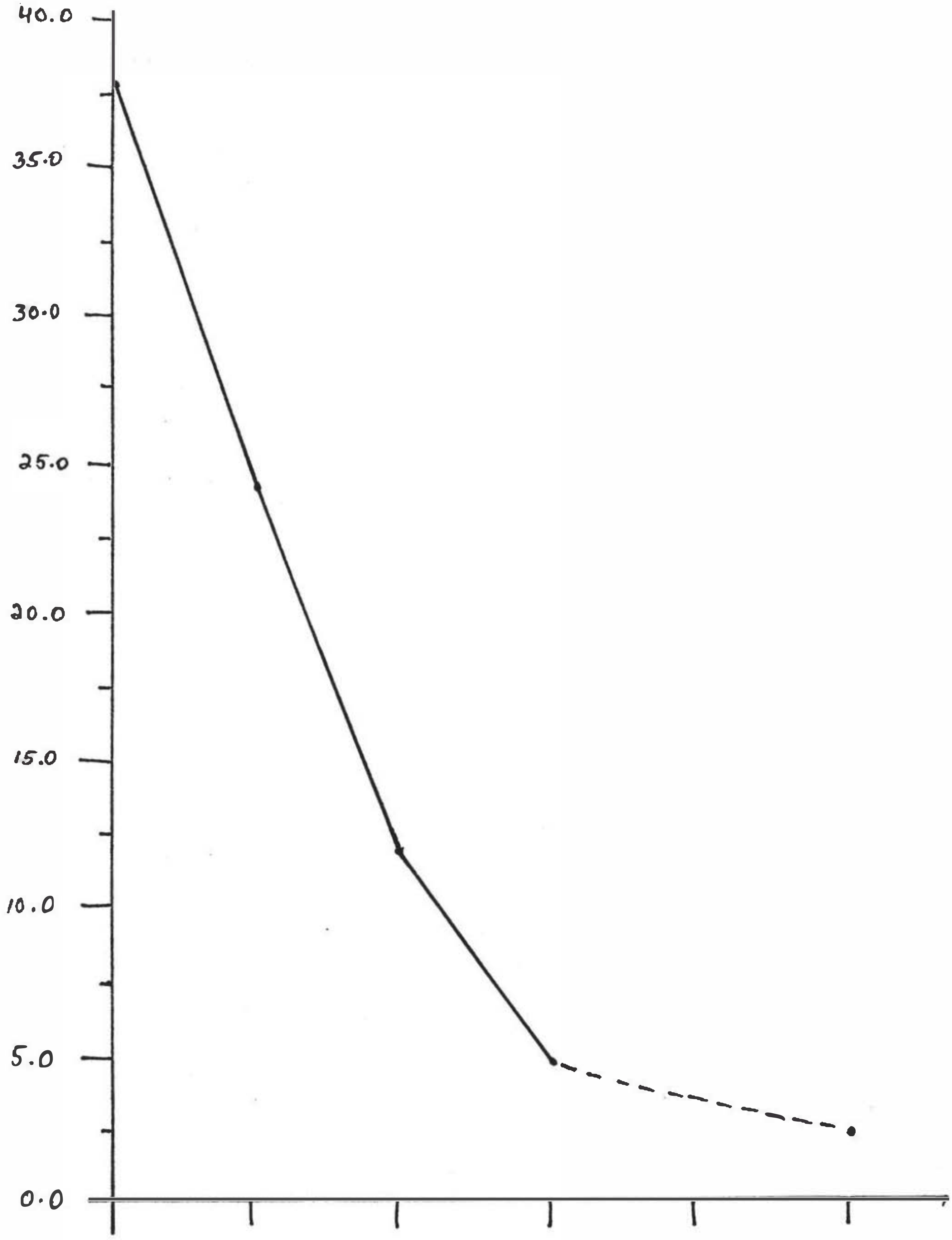
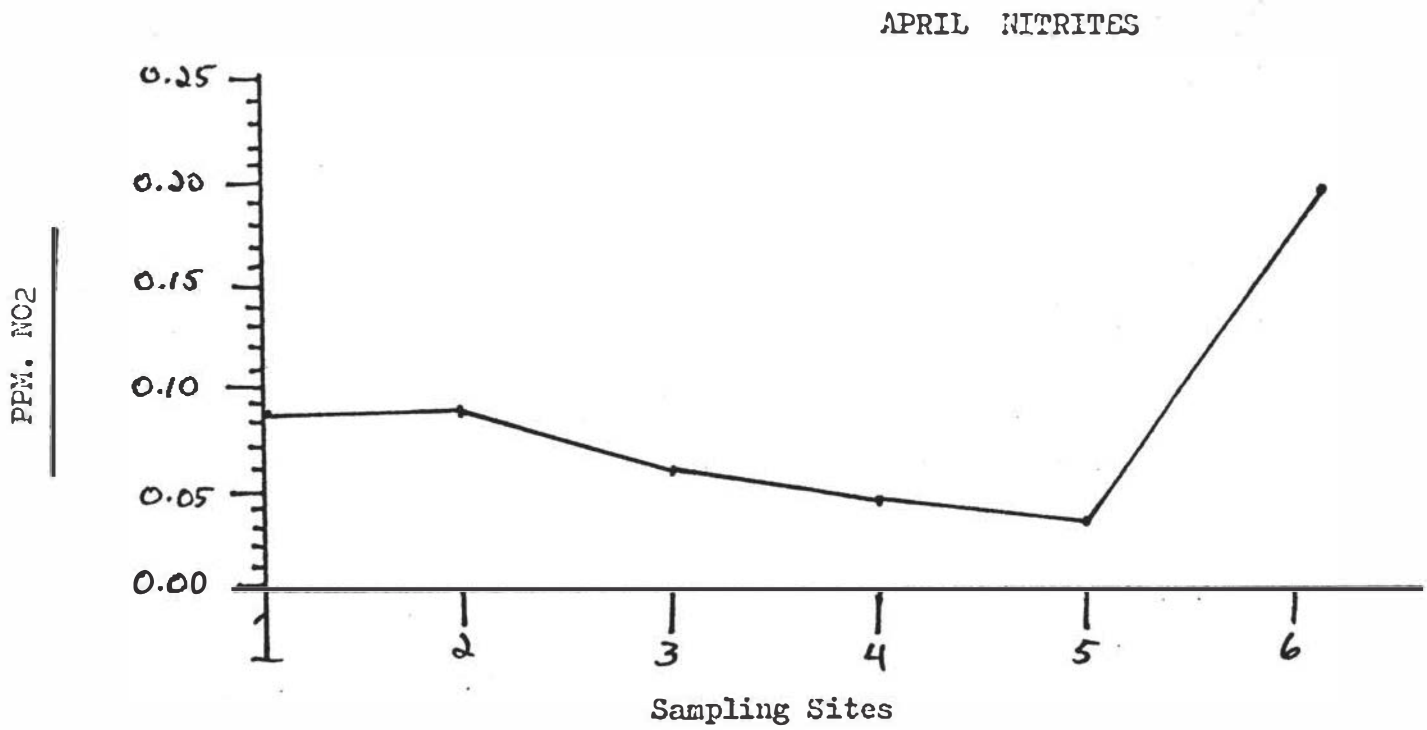


Figure 17



MEAN NO_3 VALUE / SAMPLING PERIOD

Figure 18


APRIL NITRITES
PPM. NO2
0.25
0.20
0.15
0.10
0.05
0.00
1
2
3
4
5
6
Sampling Sites

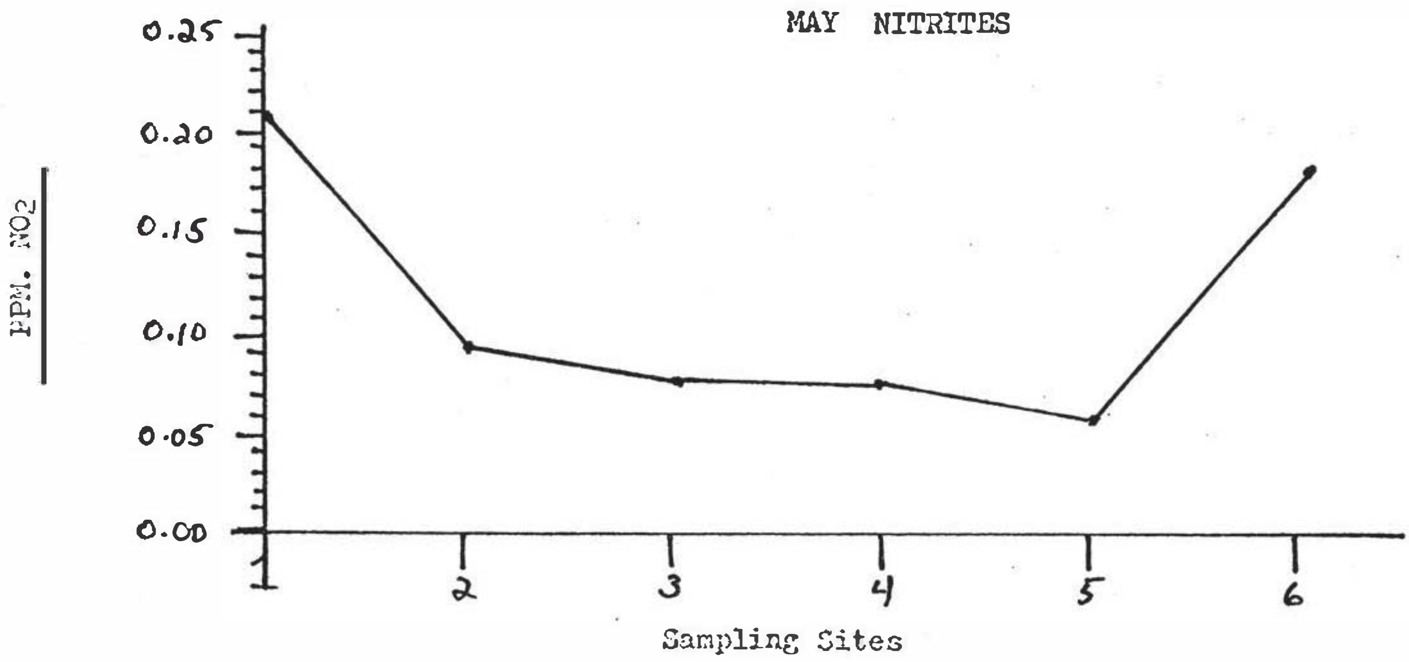
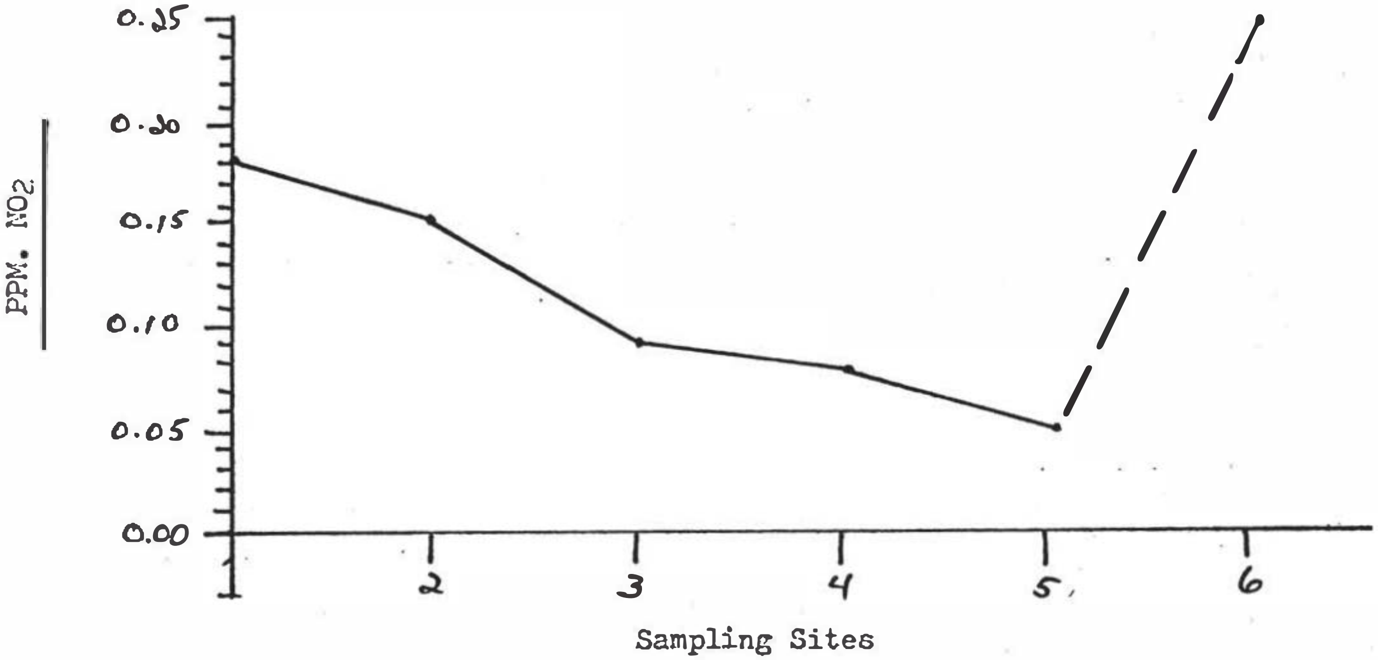

MAY NITRITES
PPM. NO2
0.25
0.20
0.15
0.10
0.05
0.00
1
2
3
4
5
6
Sampling Sites

Figure 19

JUNE NITRITES



JULY NITRITES

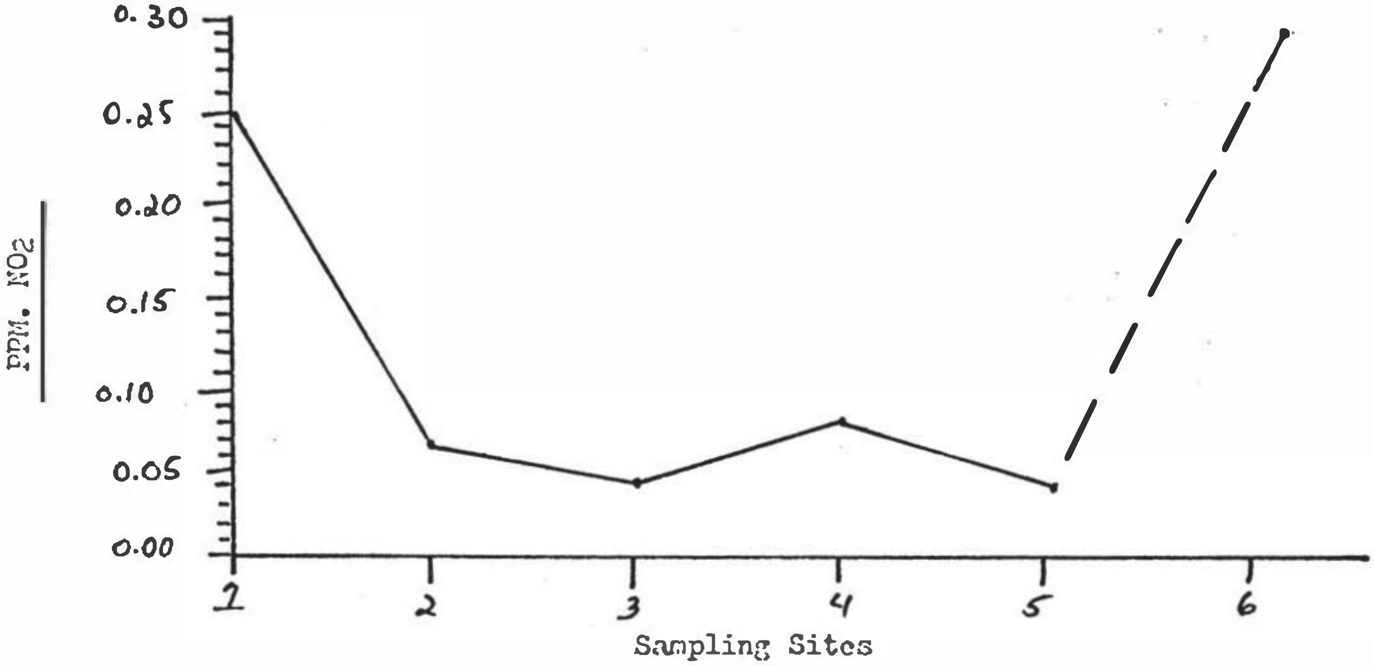
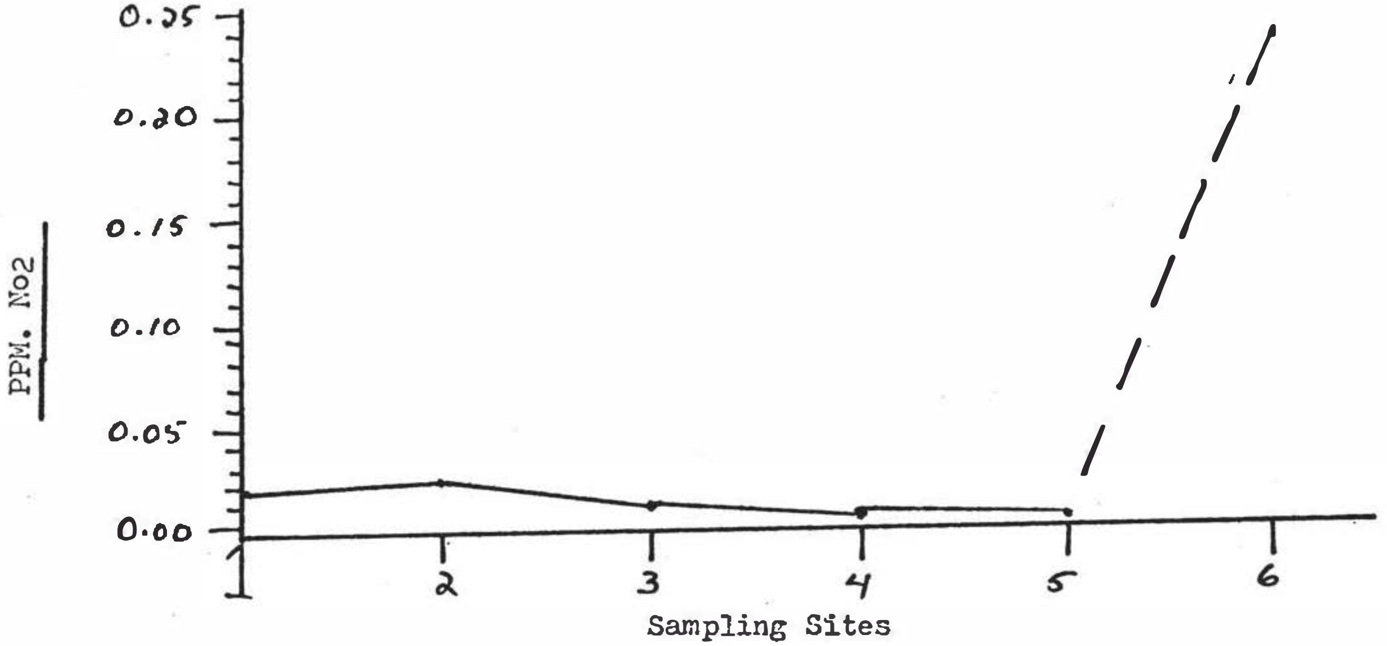


Figure 20

OCTOBER NITRITES



NOVEMBER NITRITES

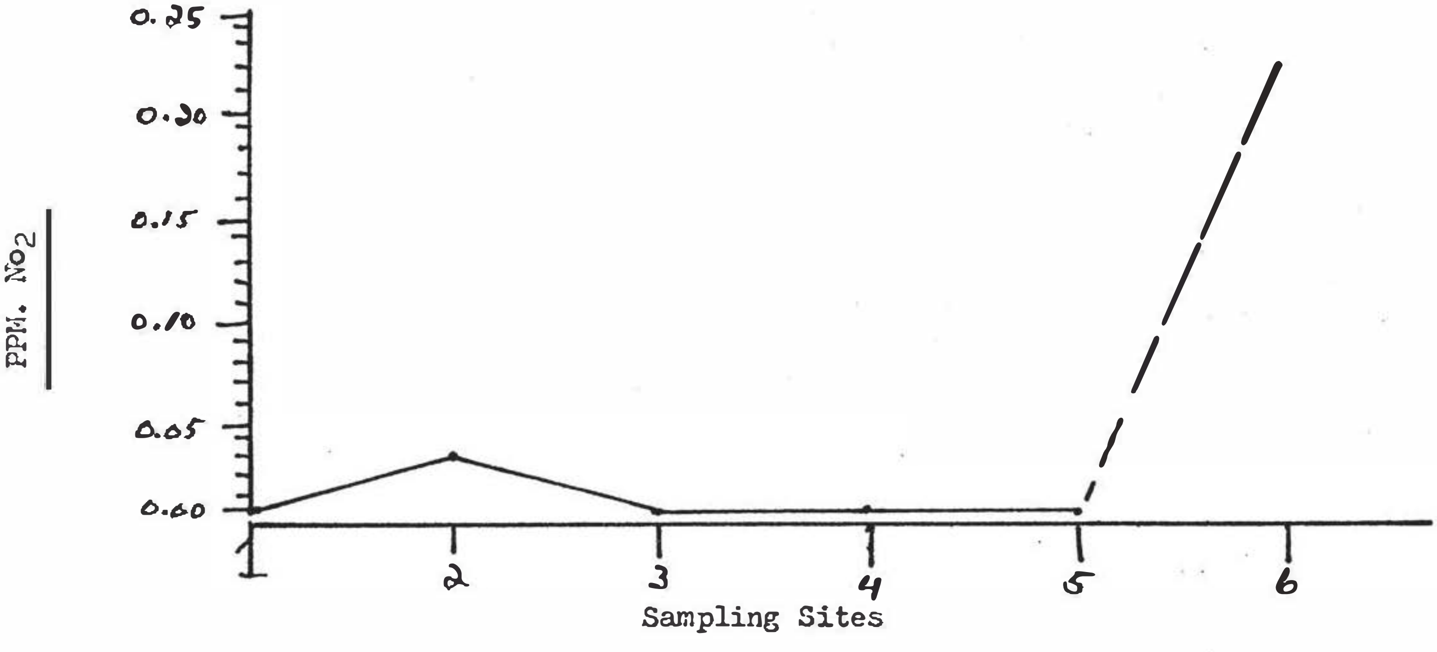
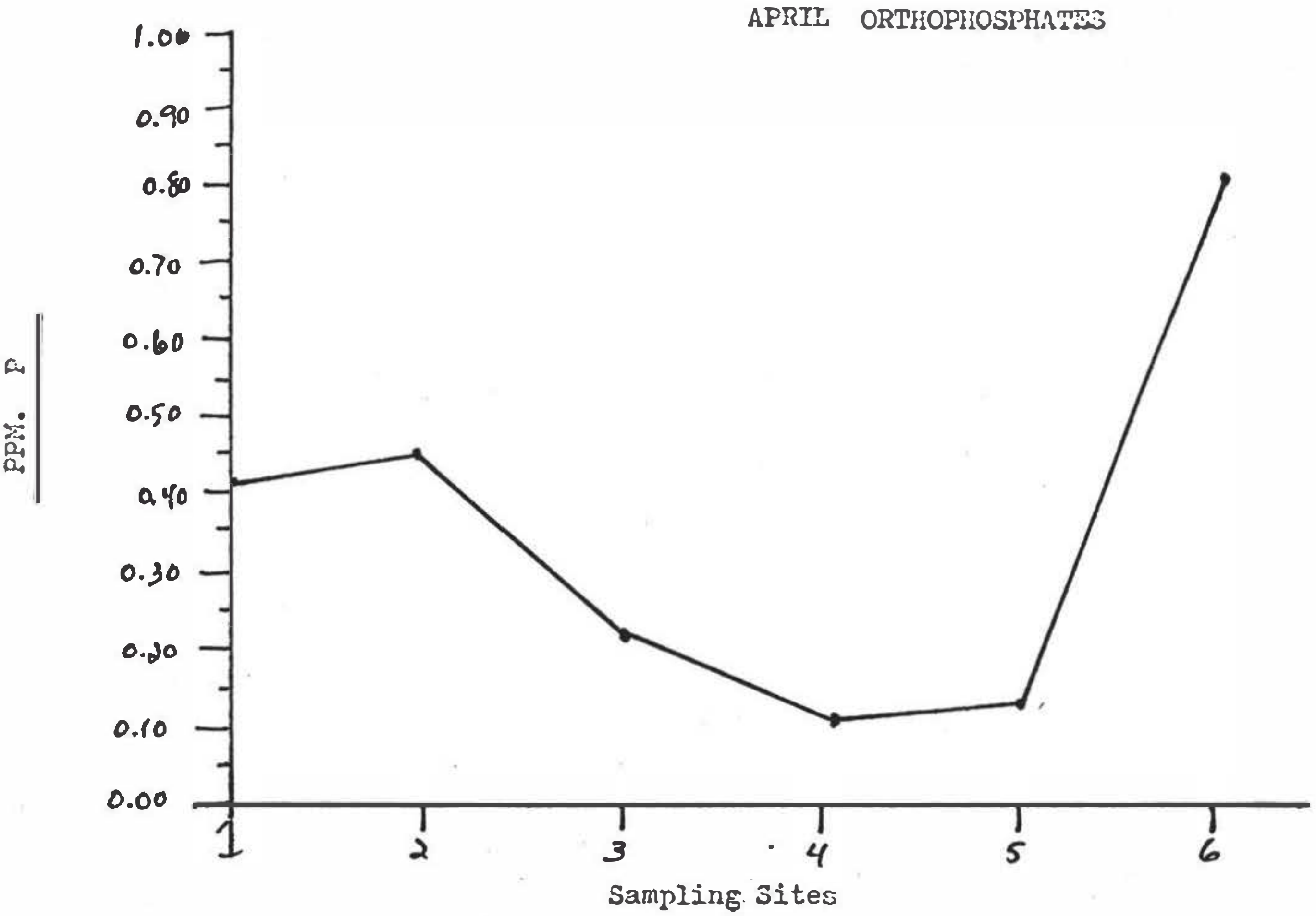
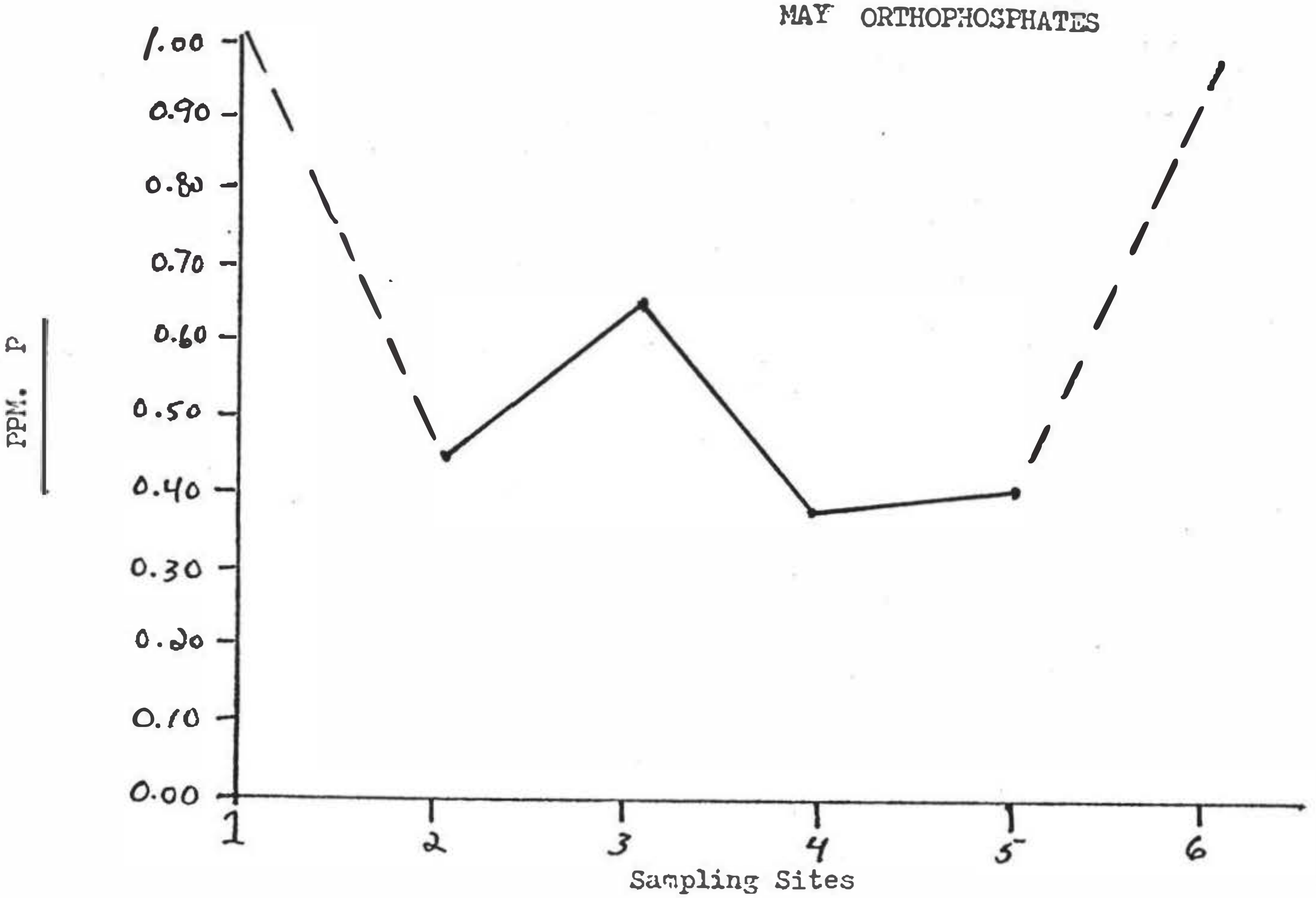


Figure 21



APRIL ORTHOPHOSPHATES
PPM. P
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
1
2
3
4
5
6
Sampling Sites



MAY ORTHOPHOSPHATES
PPM. P
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
1
2
3
4
5
6
Sampling Sites

Figure 22

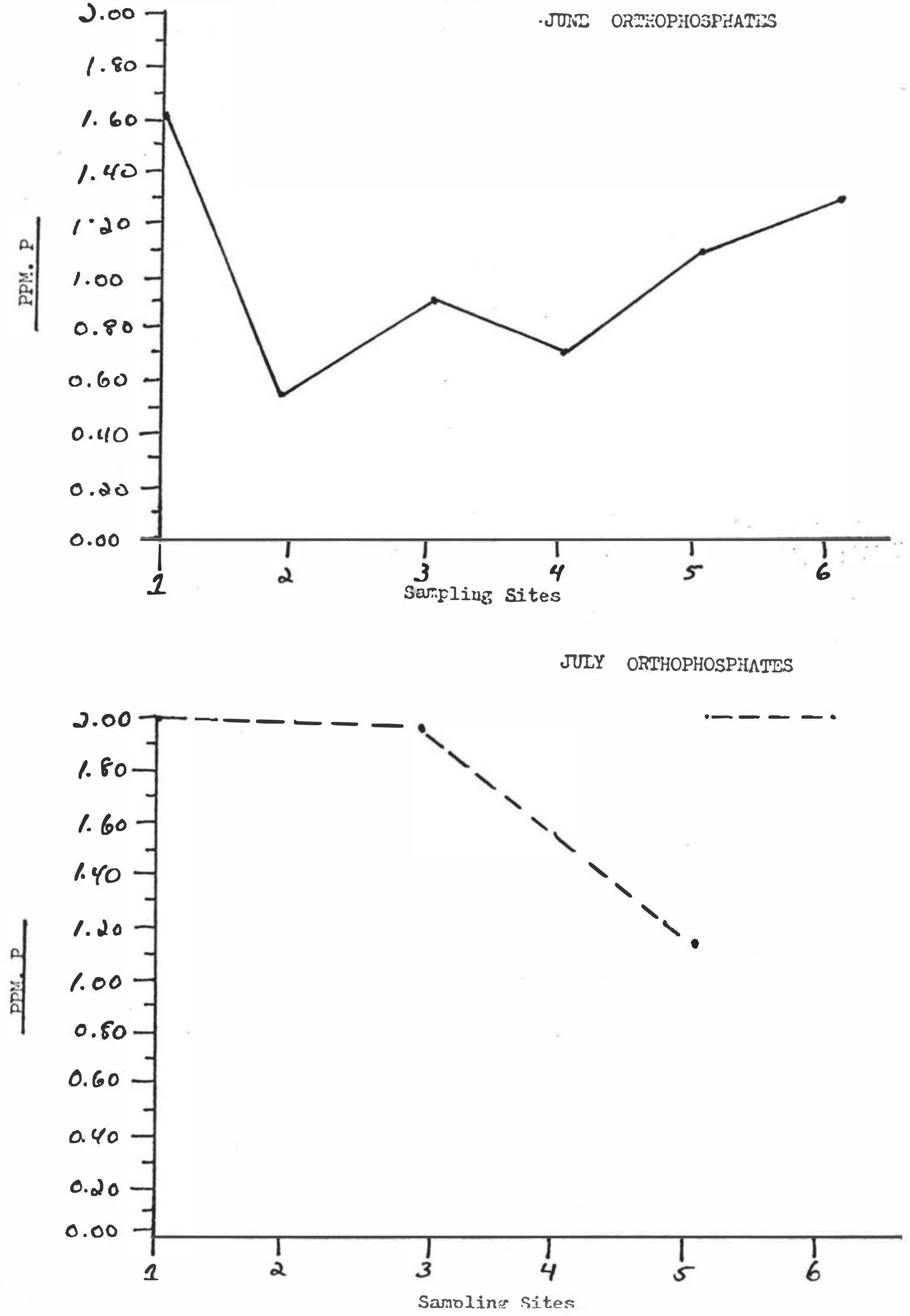
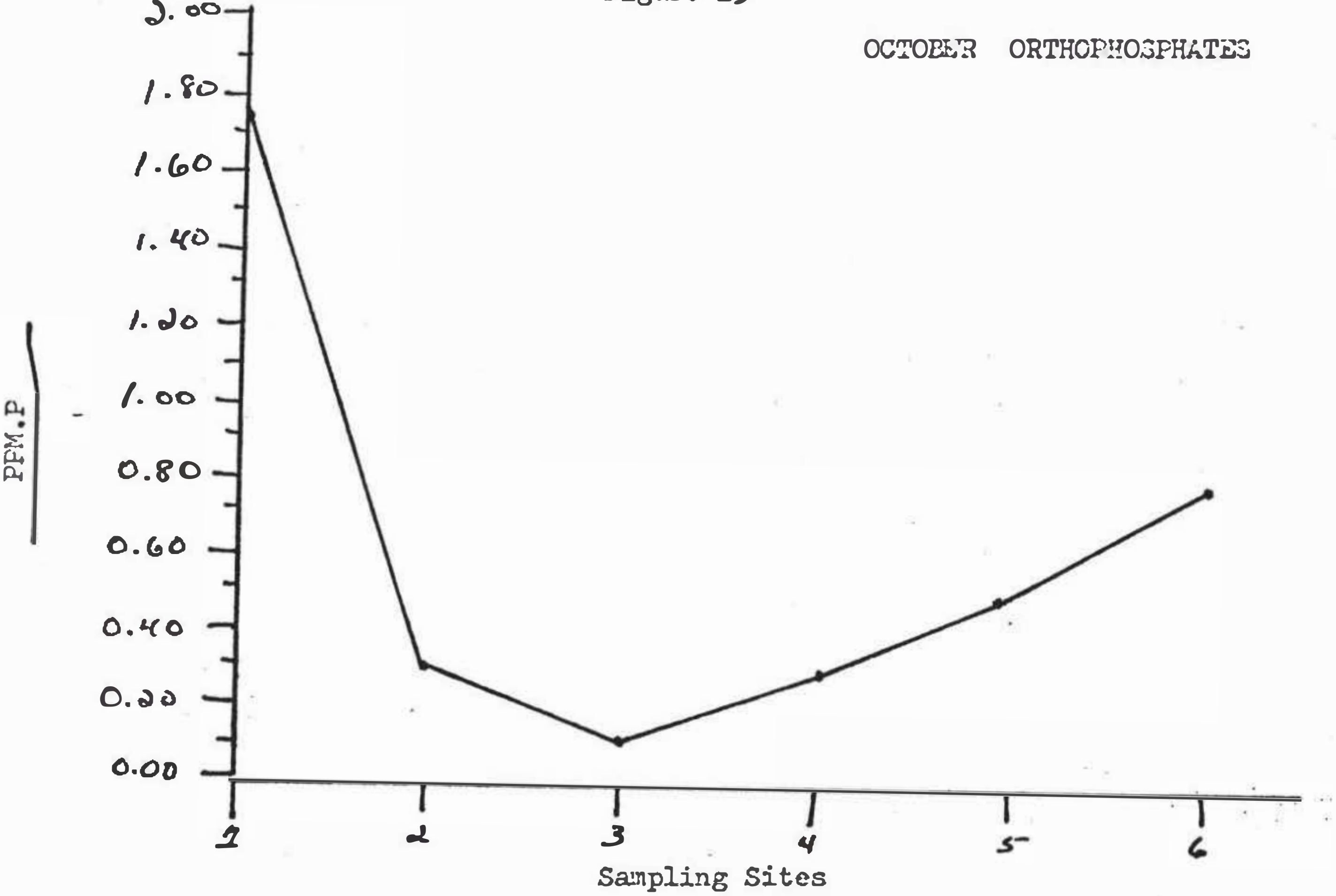

JUNE ORTHOPHOSPHATES
2.00
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
PPM. P
1
2
3
4
5
6
Sampling Sites
JULY ORTHOPHOSPHATES
2.00
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
PPM. P
1
2
3
4
5
6
Sampling Sites

Figure 23



OCTOBER ORTHOPHOSPHATES

NOVEMBER ORTHOPHOSPHATES

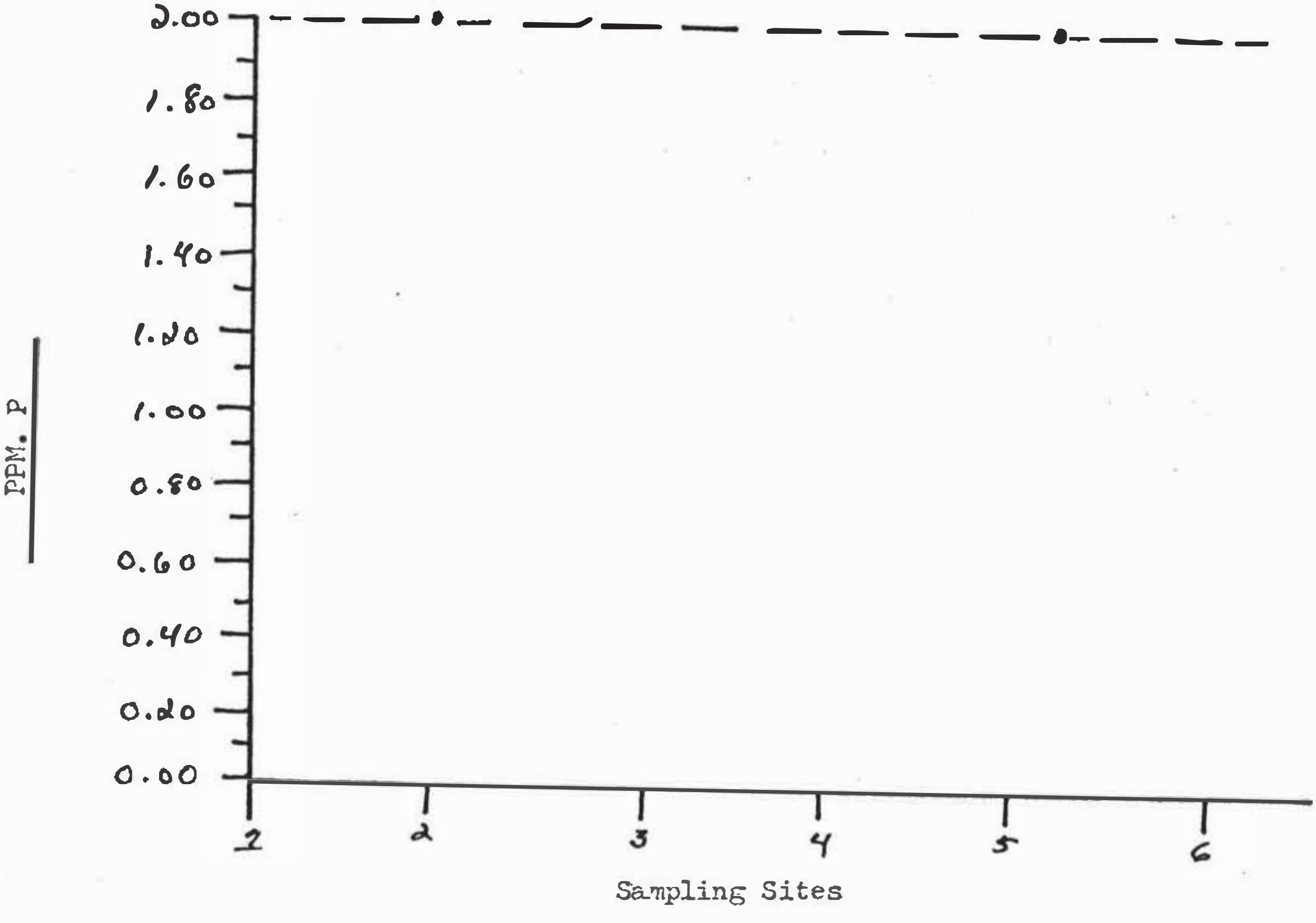
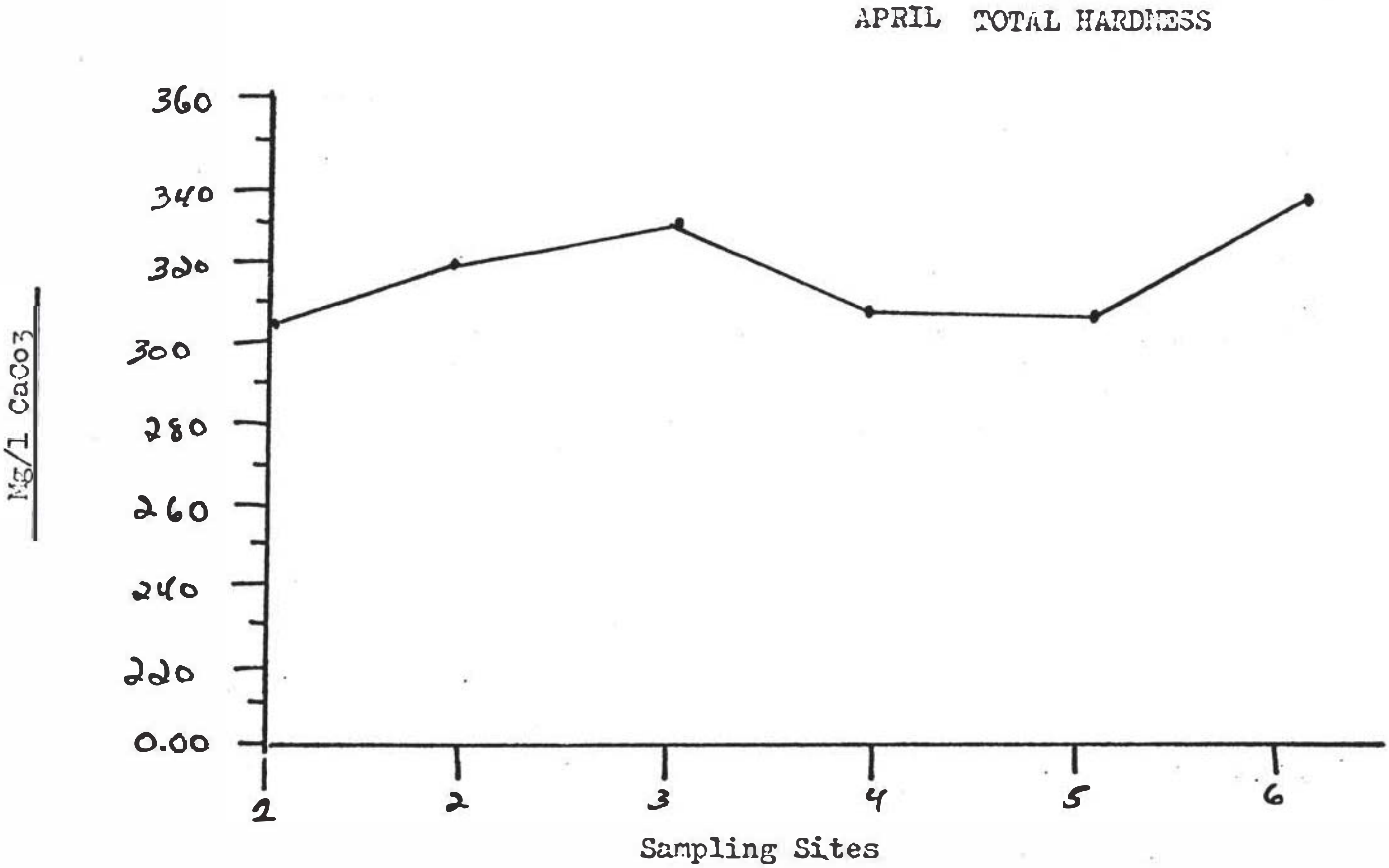


Figure 24


APRIL TOTAL HARDNESS
Mg/1 CaCo3
360
340
320
300
280
260
240
220
0.00
2
2
3
4
5
6
Sampling Sites

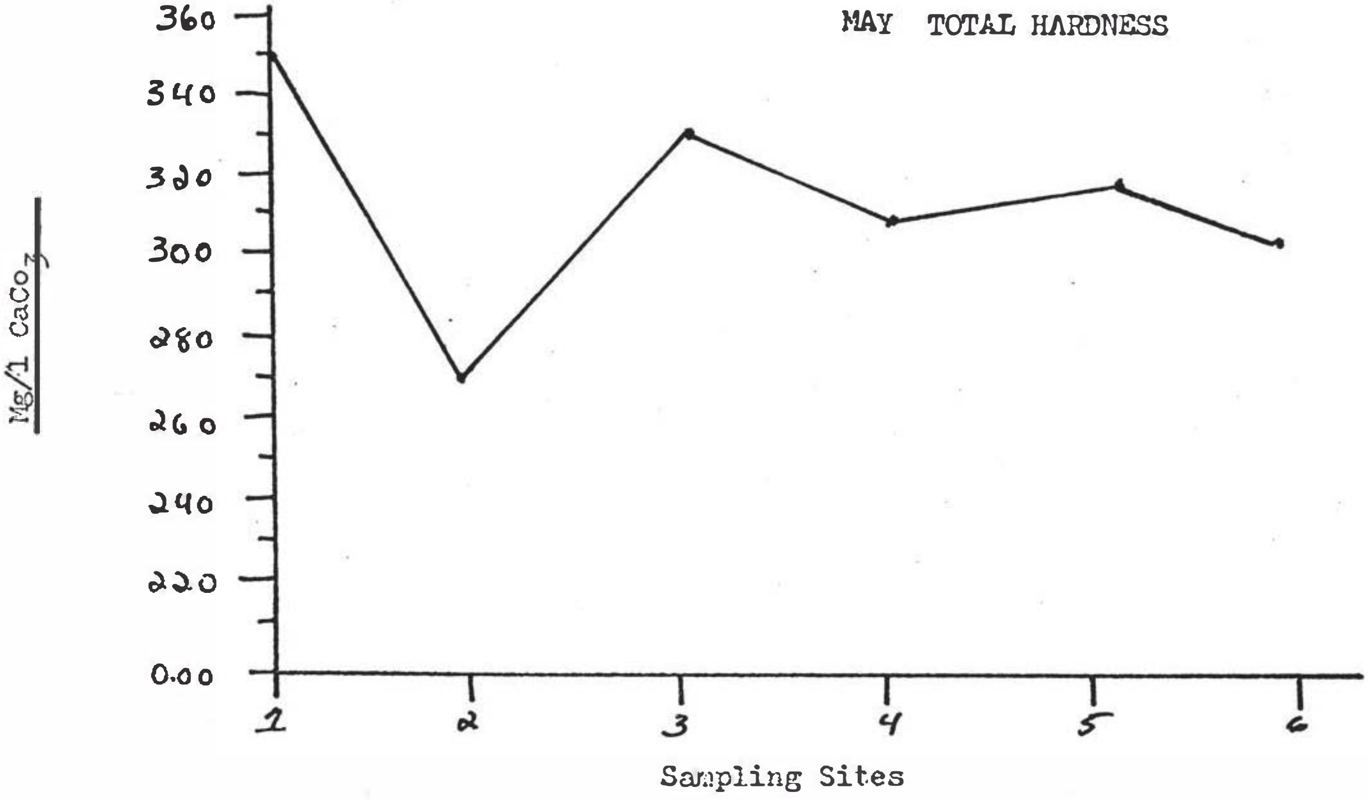
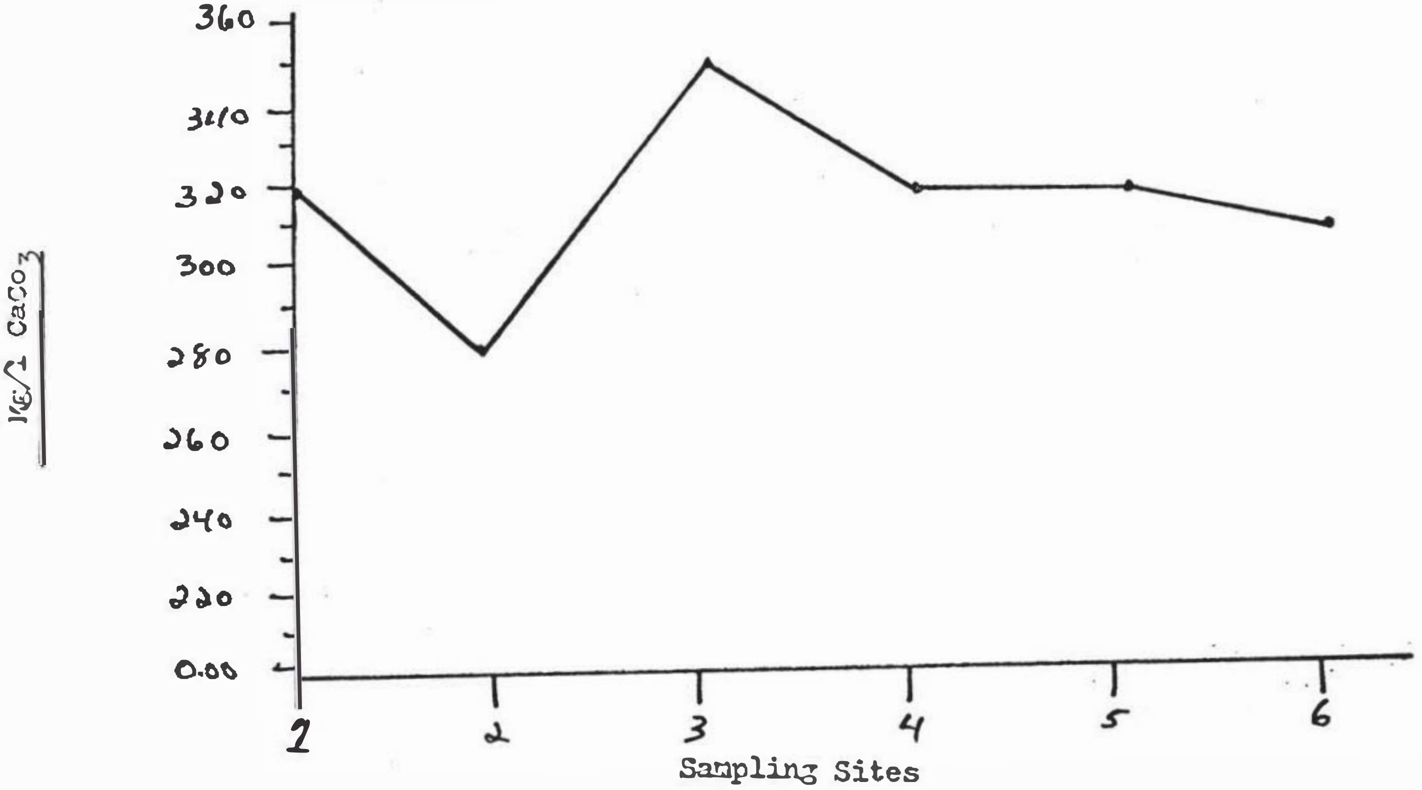
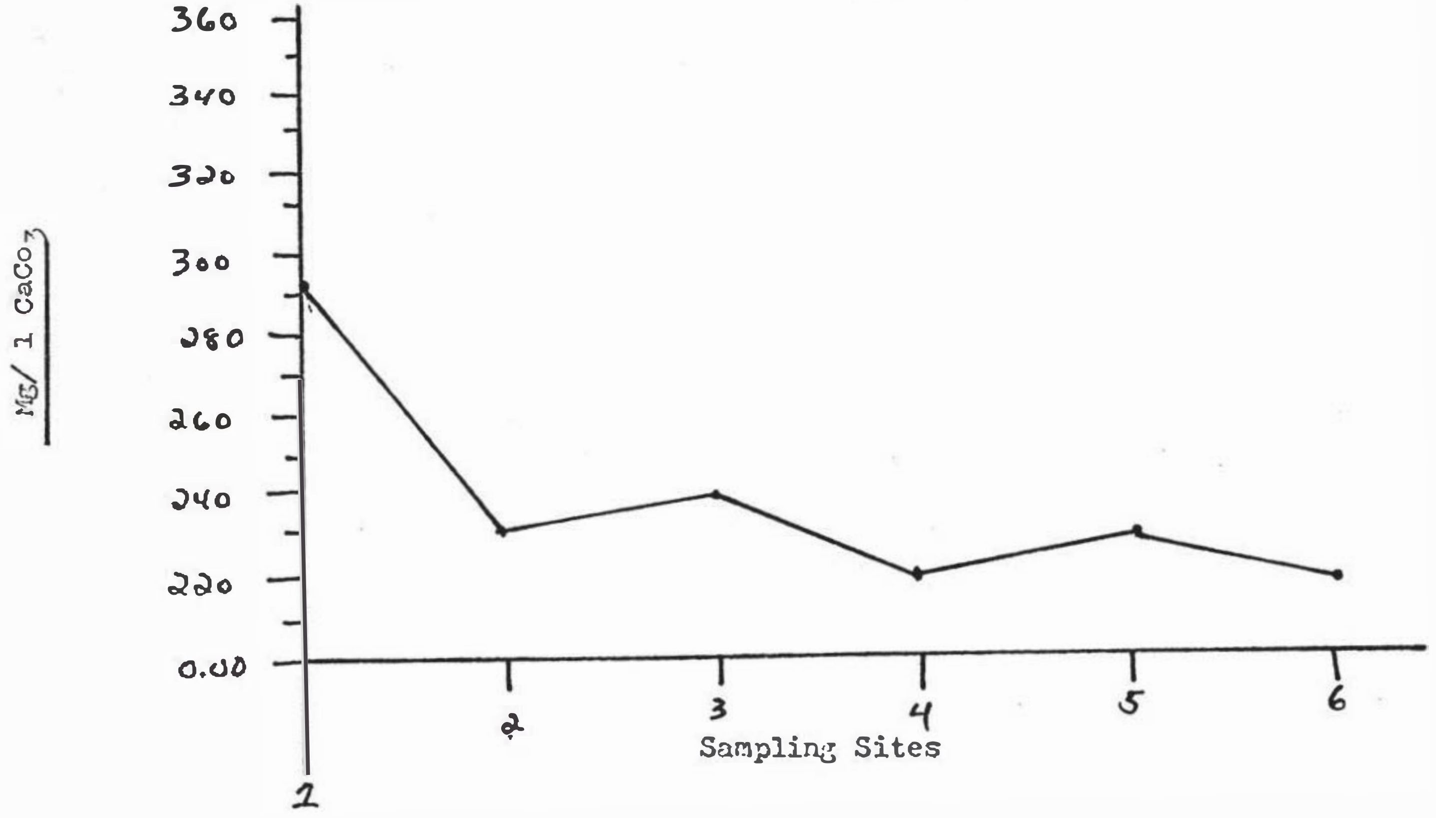

MAY TOTAL HARDNESS
Mg/1 CaCo3
360
340
320
300
280
260
240
220
0.00
1
2
3
4
5
6
Sampling Sites

Figure 25

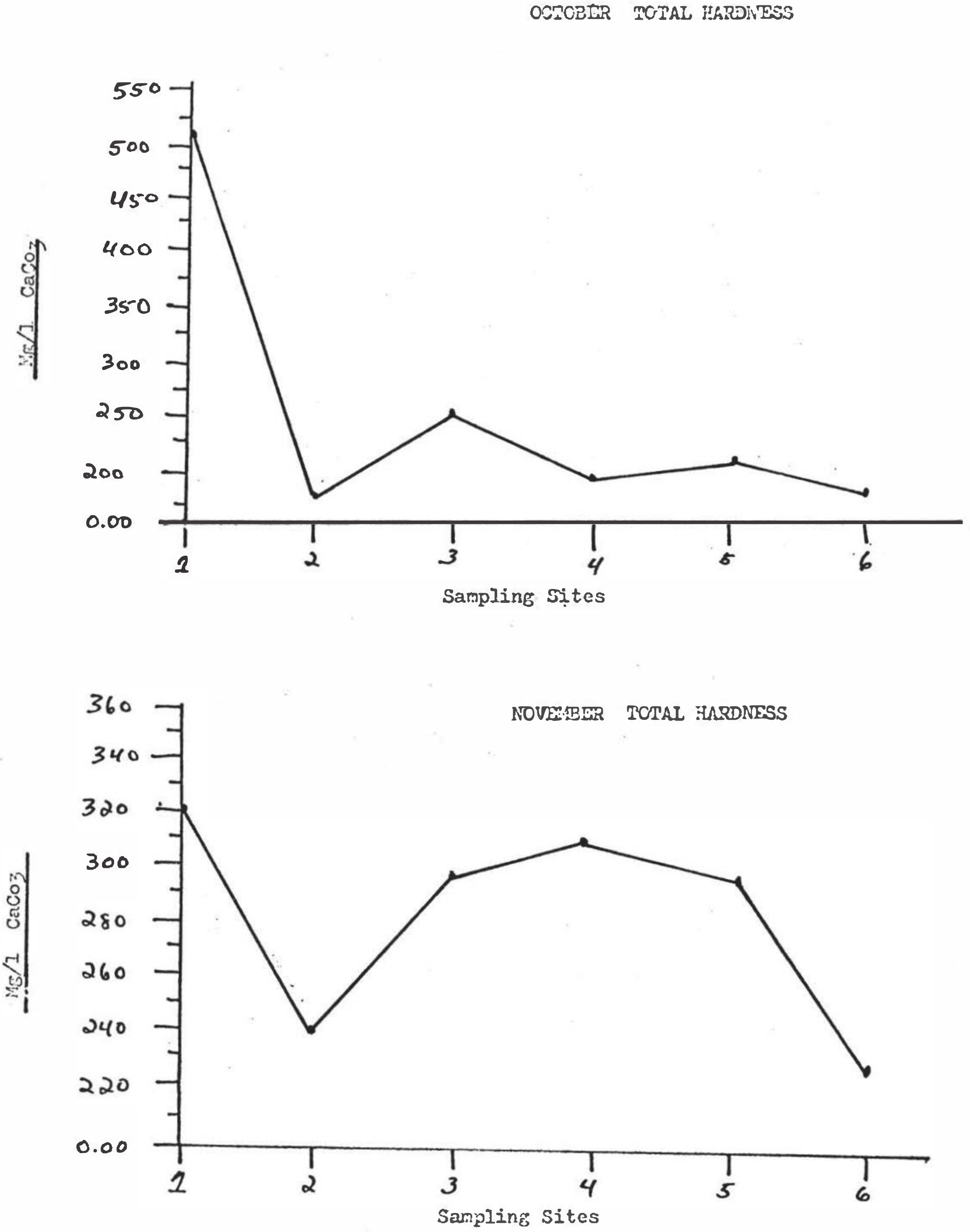


JUNE TOTAL HARDNESS



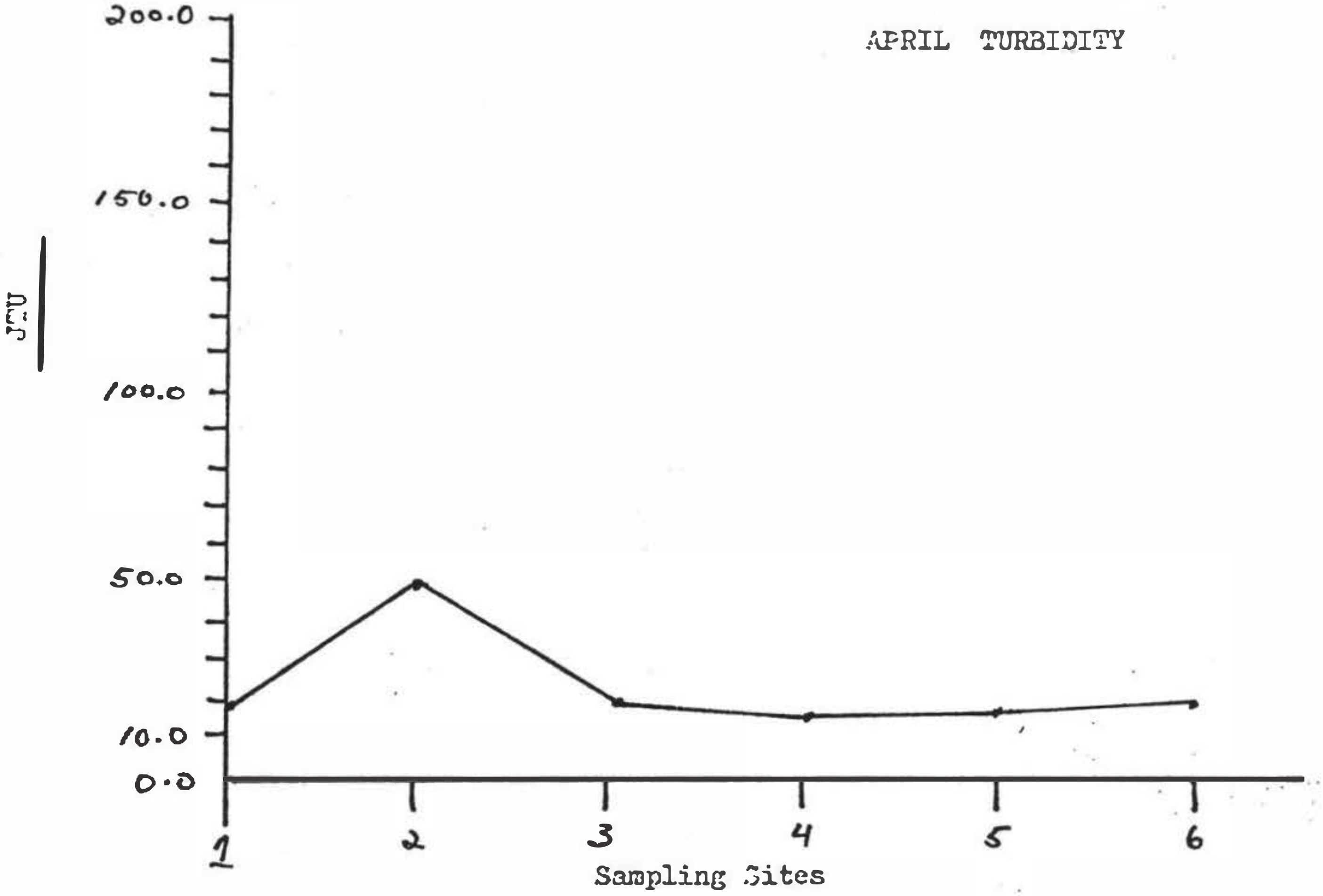
JULY TOTAL HARDNESS

Figure 26


OCTOBER TOTAL HARDNESS

NOVEMBER TOTAL HARDNESS

Figure 27


APRIL TURBIDITY
JTU
200.0
150.0
100.0
50.0
10.0
0.0
1
2
3
4
5
6
Sampling Sites

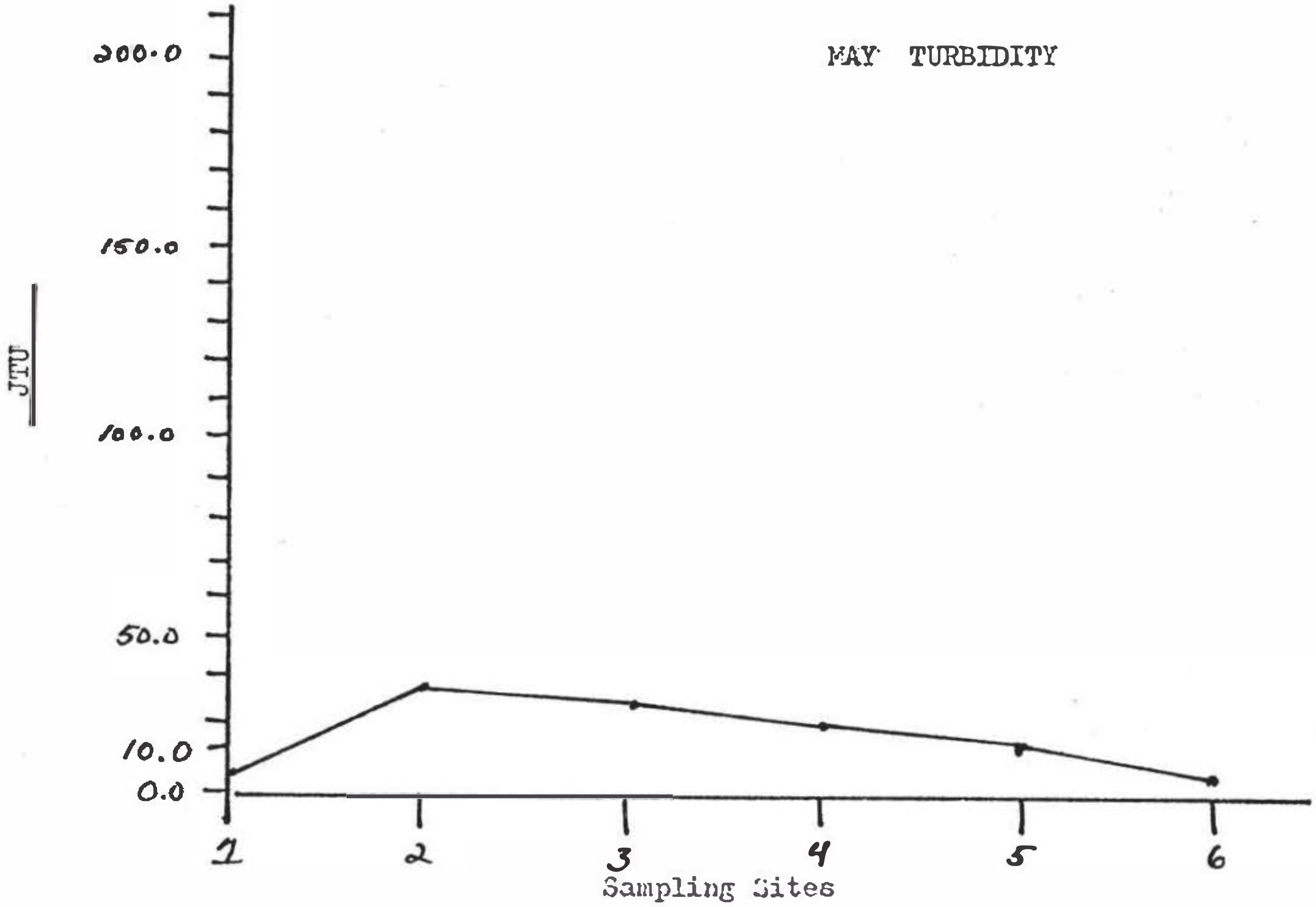

MAY TURBIDITY
JTU
200.0
150.0
100.0
50.0
10.0
0.0
1
2
3
4
5
6
Sampling Sites

Figure 28

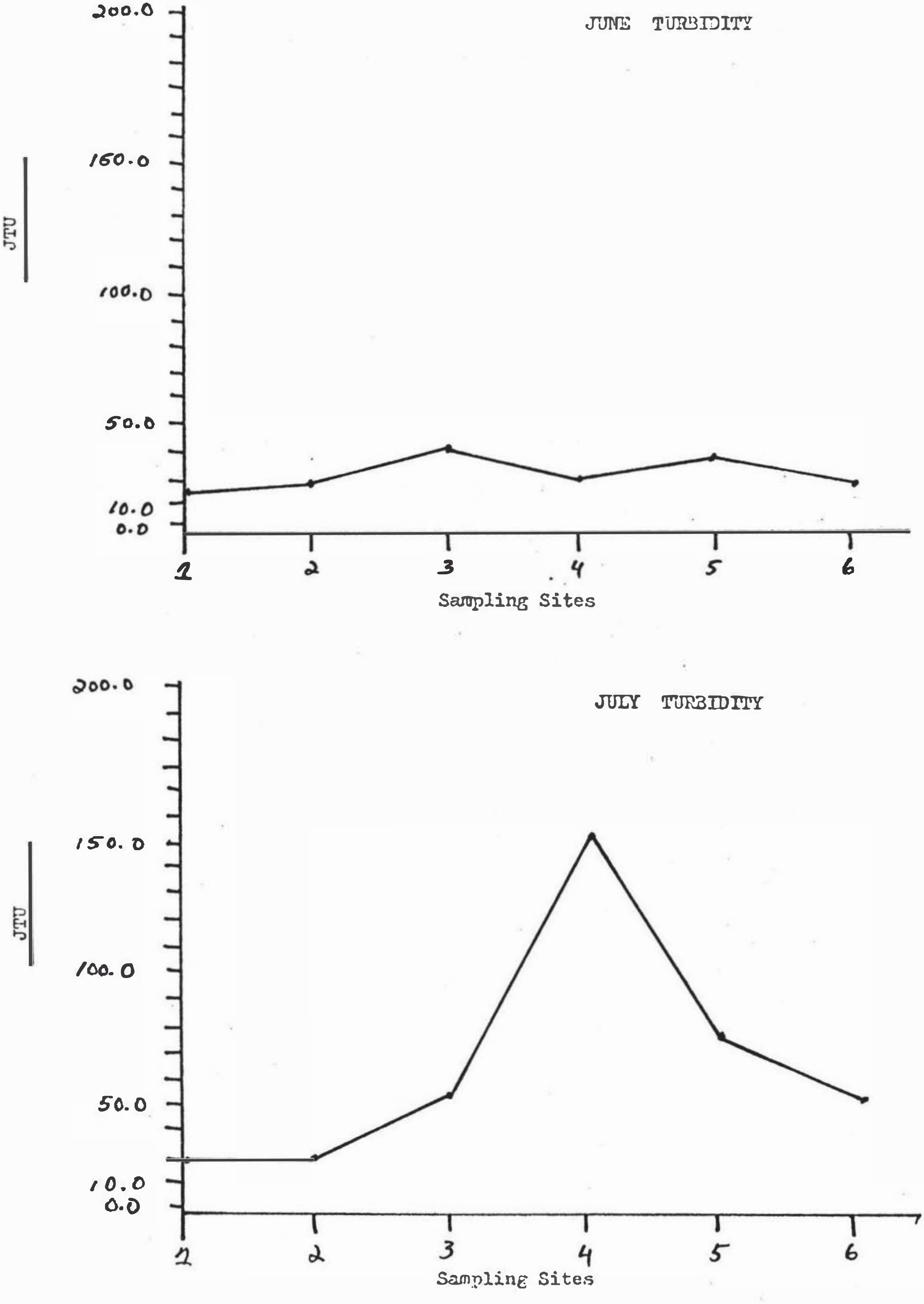
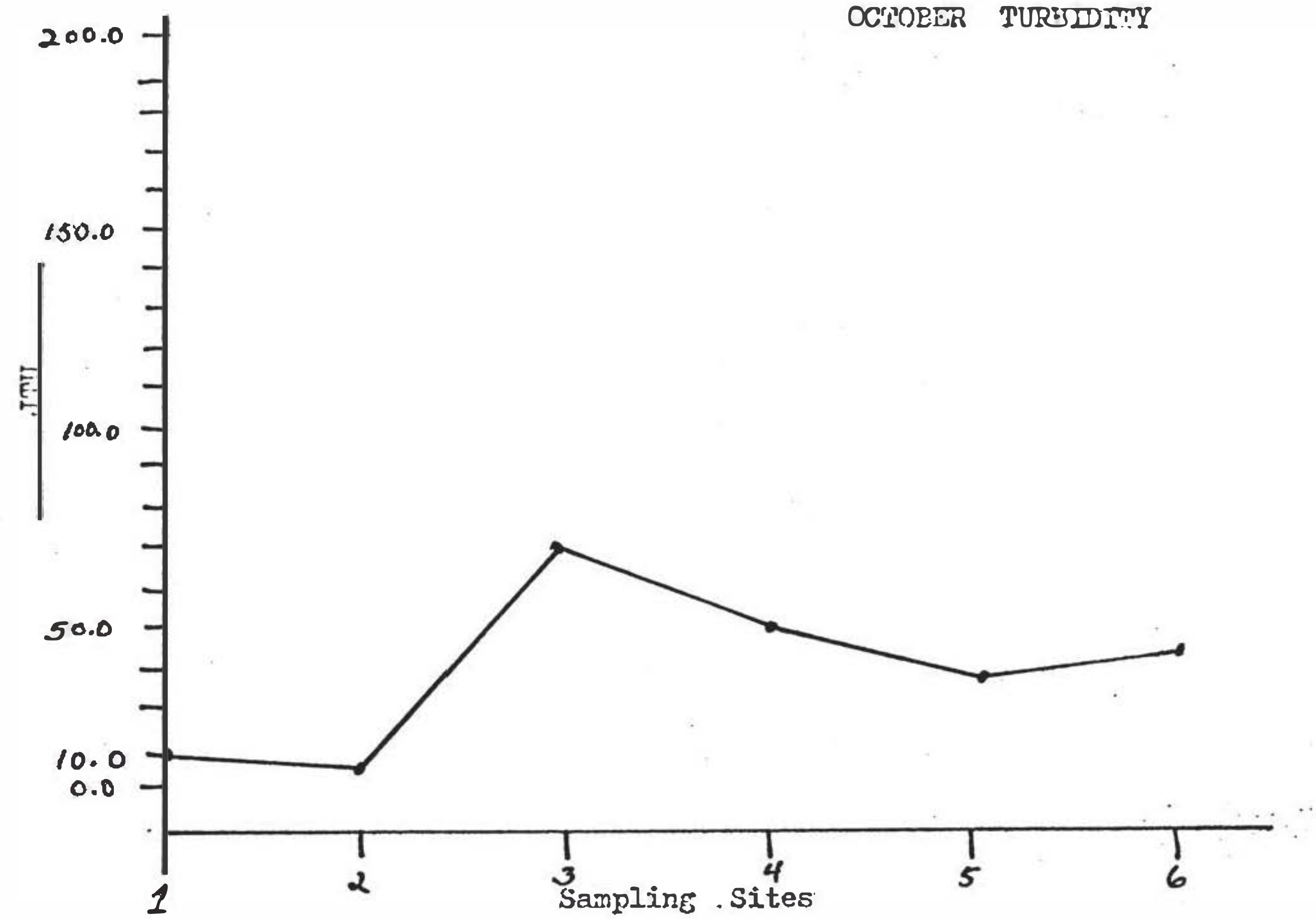
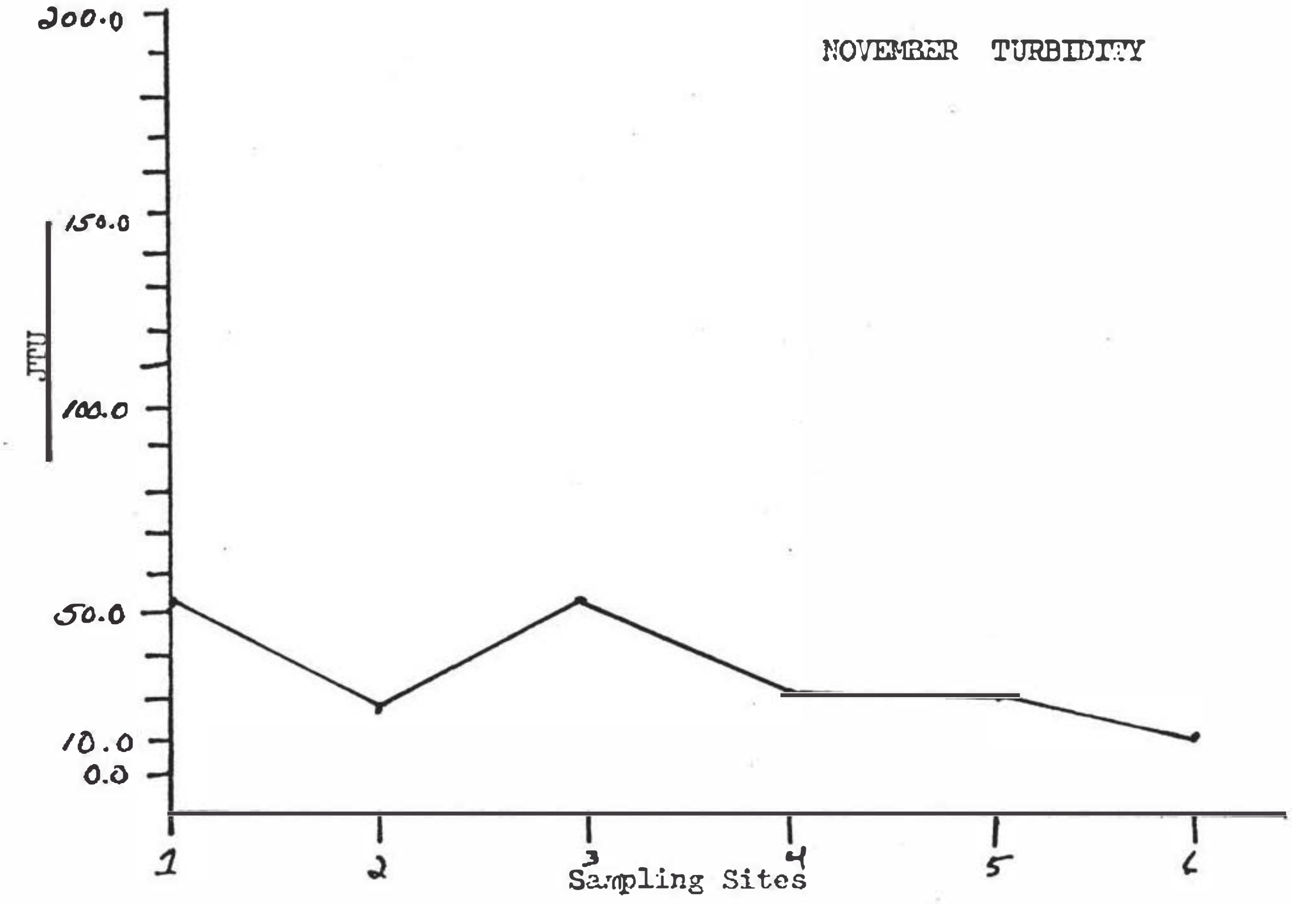

JUNE TURBIDITY
200.0
160.0
100.0
50.0
10.0
0.0
JTU
1
2
3
4
5
6
Sampling Sites
JULY TURBIDITY
200.0
150.0
100.0
50.0
10.0
0.0
JTU
1
2
3
4
5
6
Sampling Sites

Figure 29



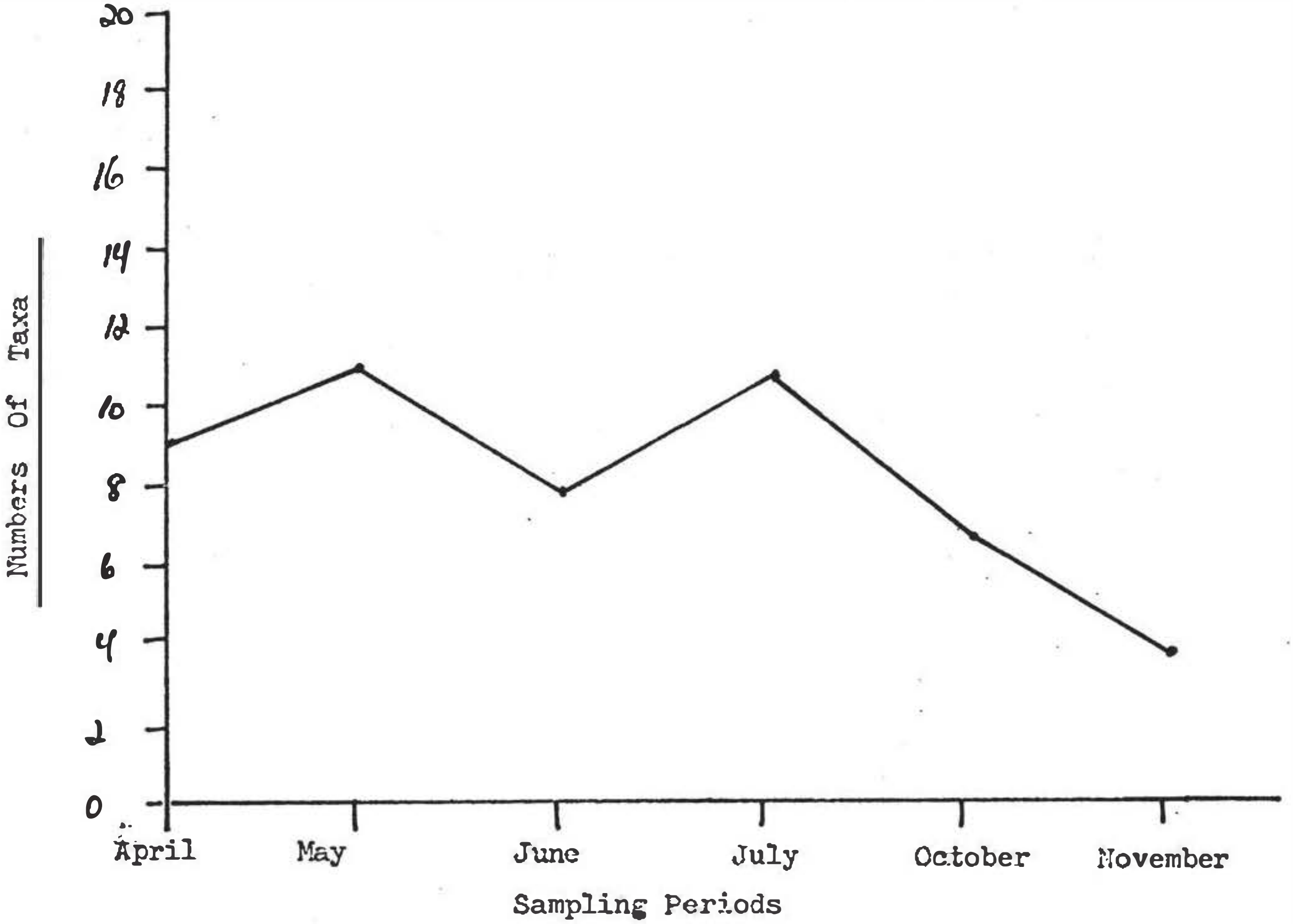
OCTOBER TURBIDITY
200.0
150.0
100.0
50.0
10.0
0.0
JTU
1
2
3
4
5
6
Sampling Sites



NOVEMBER TURBIDITY
200.0
150.0
100.0
50.0
10.0
0.0
JTU
1
2
3
4
5
6
Sampling Sites

Figure 30

Sampling Site # 1



Sampling Site # 2

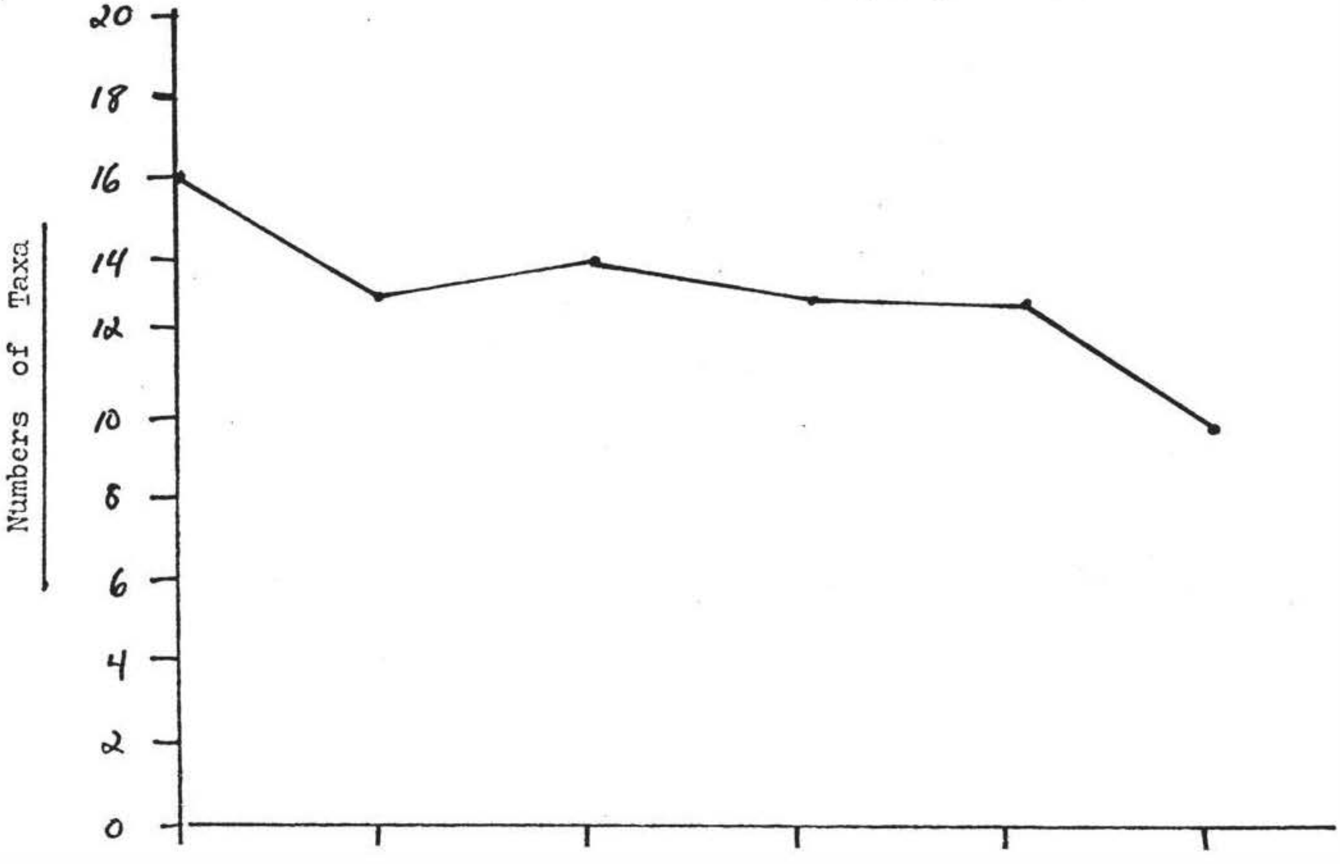
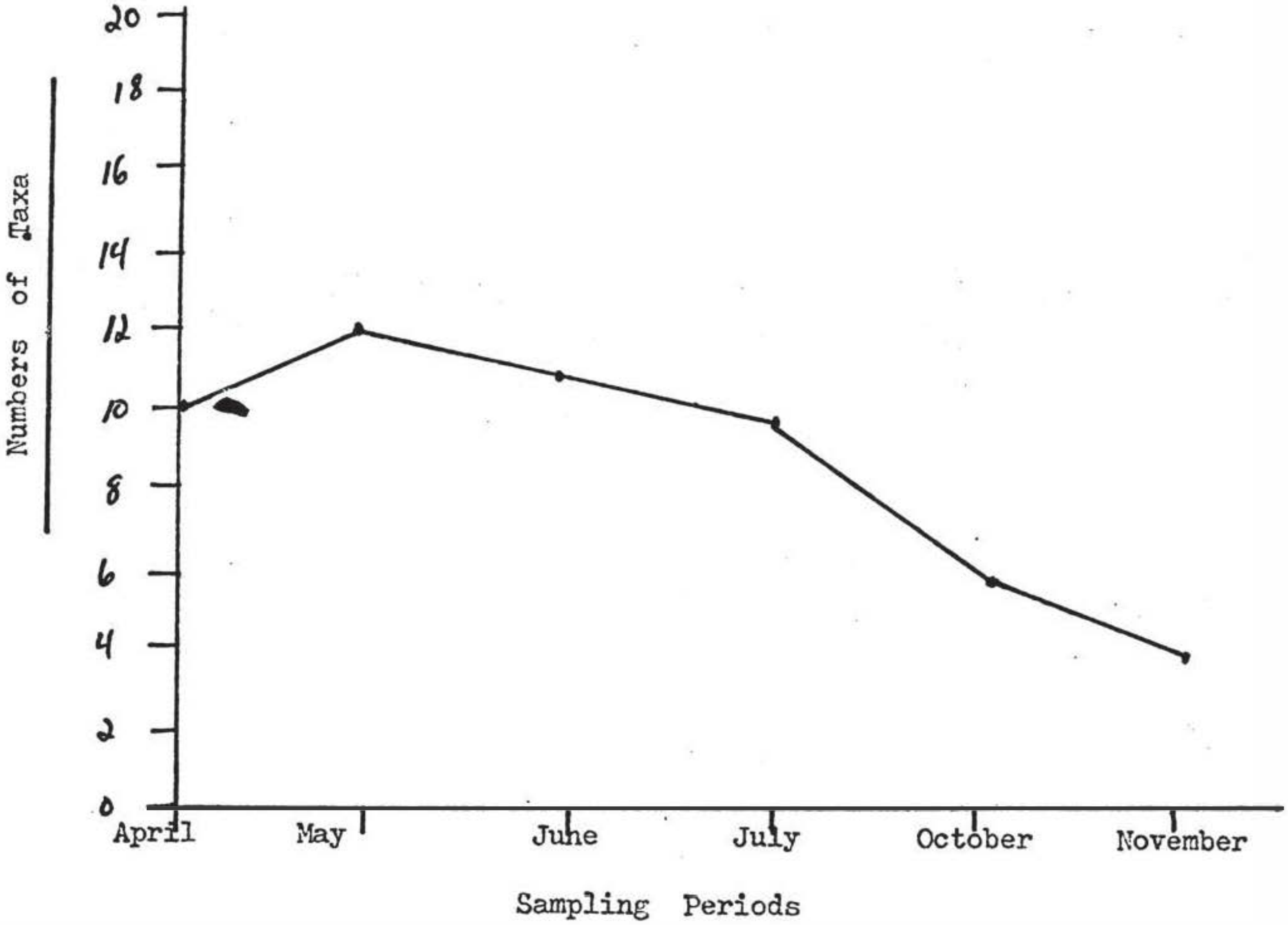


Figure 31

Sampling Site # 3



Sampling Site # 4

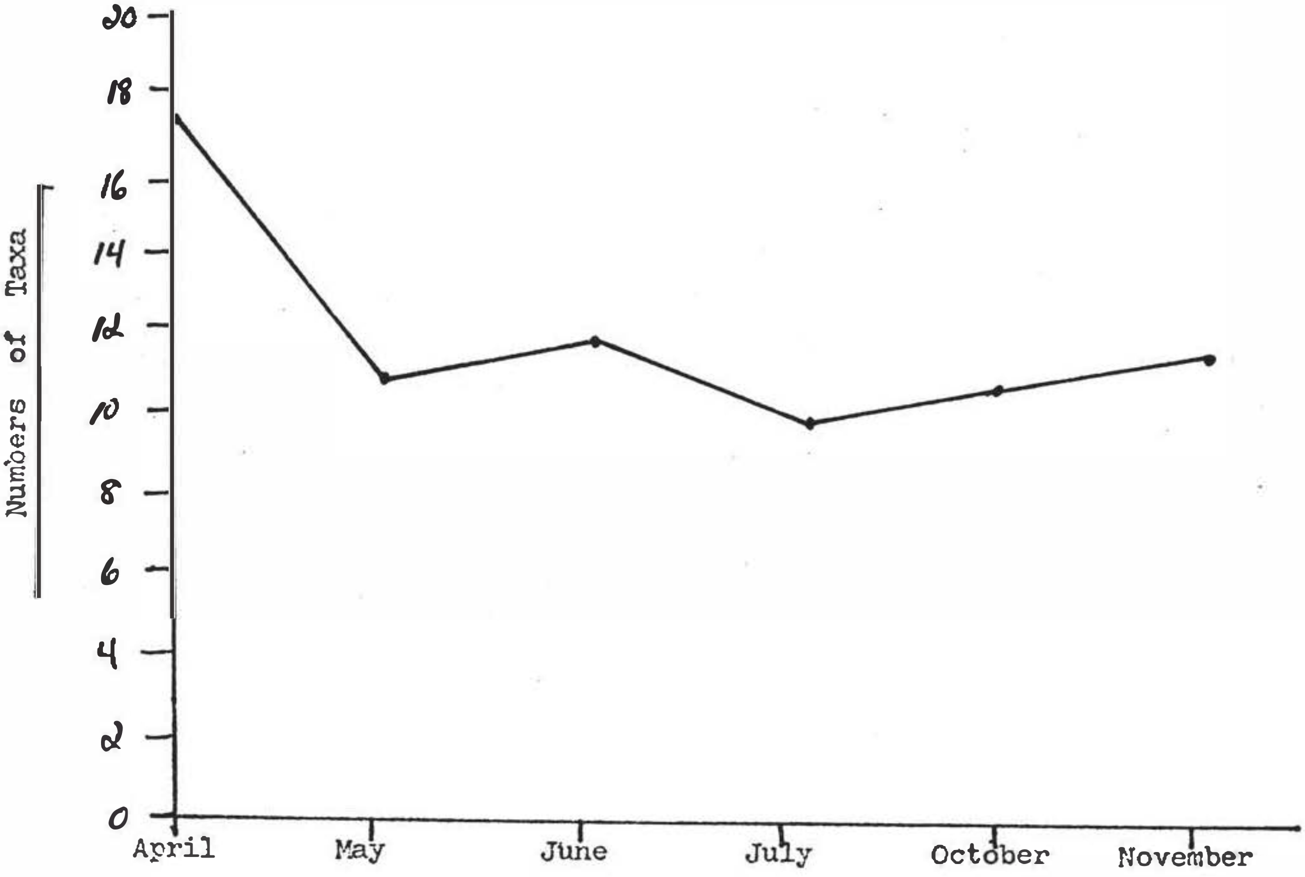
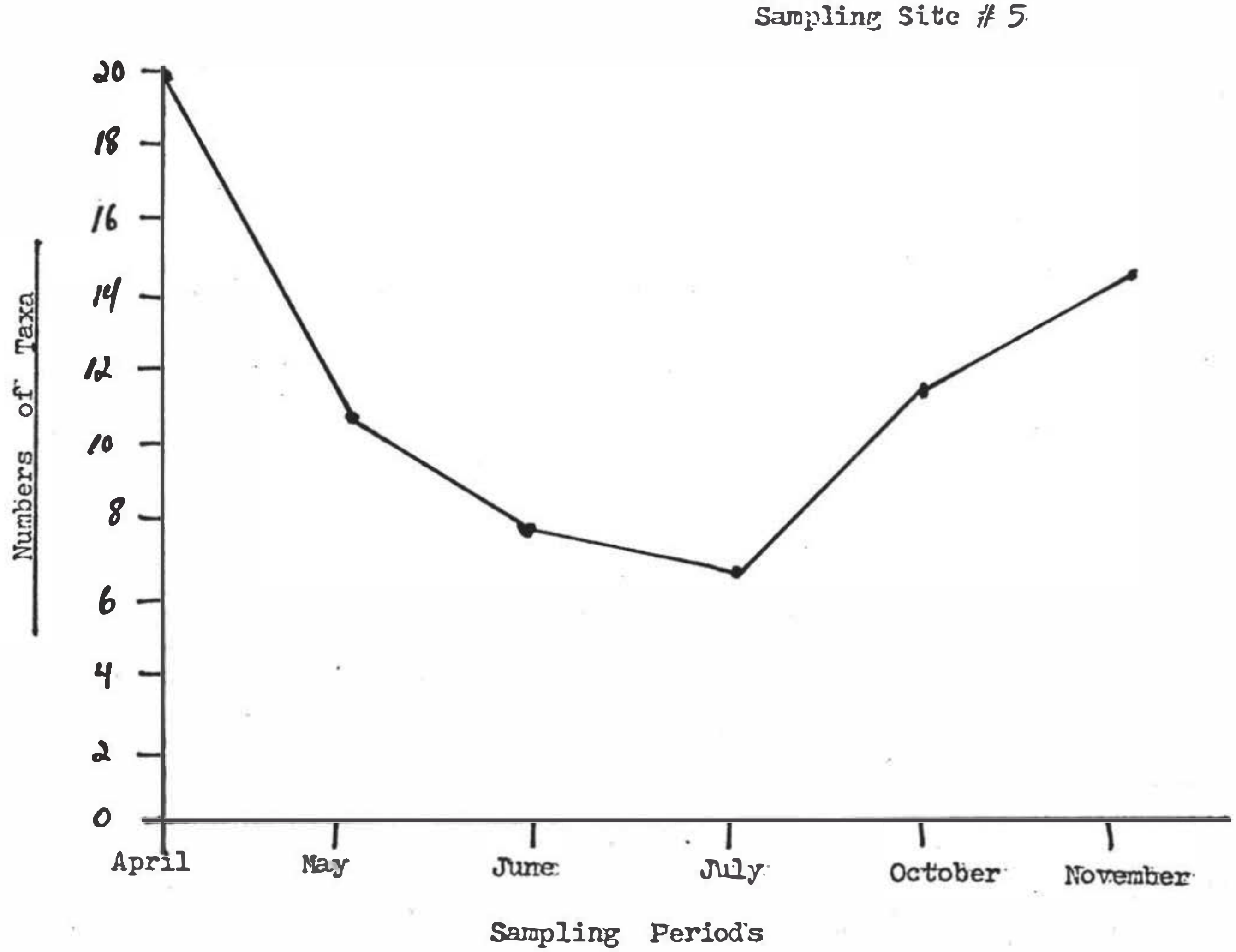


Figure 32


Sampling Site # 5
20
18
16
14
12
10
8
6
4
2
0
Numbers of Taxa
April
May
June
July
October
November
Sampling Periods

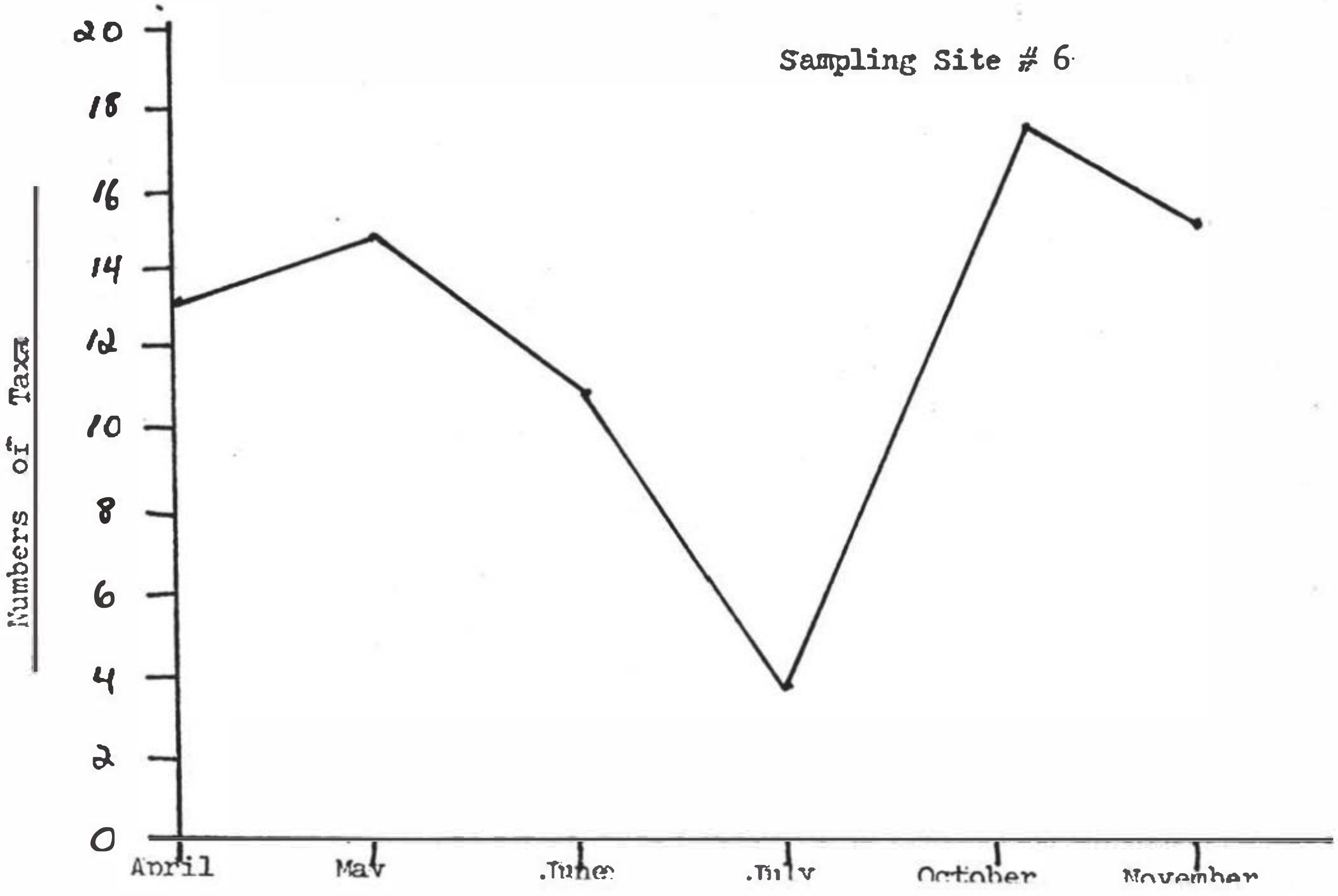

Sampling Site # 6
20
18
16
14
12
10
8
6
4
2
0
Numbers of Taxa
April
May
June
July
October
November

TABLE 1: Summary of water quality parameters for the months of April, May, June, July, October and November, 1976.

PARAMETER AND SITE	RANGE	MEAN
Water Temperature (^{o}Centigrade)		
SITE # 1	0.0 - 27.0	16.2
2	2.0 - 28.0	17.5
3	1.0 - 26.0	16.9
4	1.0 - 26.0	16.7
5	1.0 - 26.0	16.7
6	5.0 - 27.0	17.3
D.O. (PPM O_2)		
SITE # 1	0.7 - 9.8	4.8
2	3.4 -11.2	7.9
3	3.0 -11.2	6.9
4	1.9 -11.1	6.5
5	2.0 -10.5	6.8
6	3.3 -11.8	8.0
B.O.D. (Mg/L O_2)		
SITE # 1	1.8 -32.4	10.2
2	1.9 -15.0	6.4
3	1.4 -10.2	4.7
4	1.5 - 6.8	3.6
5	1.4 - 6.8	3.4
6	1.5 -11.4	3.0

TABLE 2

PARAMETER AND SITE	RANGE	MEAN
Nitrates (PPM NO_3)		
SITE #1	4.0 - 43.0	15.1
2	1.0 - 150.0	37.8
3	2.0 - 150.0	37.9
4	2.5 - 150.0	38.7
5	1.0 - 150.0	37.6
6	10.0 - 37.0	19.6
Nitrites (PPM NO_2)		
SITE #1	.01- 0.21	0.10
2	.03- 0.14	0.06
3	.01- .09	0.02
4	.01- .08	0.04
5	.01- .07	0.03
6	0.19- 0.2	0.19
Ortho-Phosphates		
SITE #1	0.4 - 2.0	1.9
2	0.4 - 2.0	1.1
3	OFF SCALE	
4		
5		
6		
Total Hardness (PPM $CACO_3$)		
SITE #1	290-520	350
2	160-320	250
3	240-350	303

TABLE 3

PARAMETER AND SITE	RANGE	MEAN
Total Hardness (PPM $CACO_3$) cont'd.		
SITE #4	200 - 320	278
5	220 - 320	283
6	180 - 340	263
Turbidity (Jackson Turbidity Units)		
SITE #1	5 - 50	21.5
2	15 - 50	26.5
3	20 - 70	40.3
4	18 -145	47.3
5	15 - 70	33.5
6	8 - 45	27.5
pH (Hydrogen Ion Concentration)		
SITE #1	6.7 - 7.8	7.3
2	6.7 - 9.3	7.8
3	6.7 - 8.2	7.5
4	6.9 - 8.1	7.4
5	6.9 - 9.0	7.7
6	6.7 - 8.3	7.4

TABLE 4

SITE # 1	T - 7 - 41%	STREAM CLASSIFICATION OF SITE #1:
	F - 4 - 24%	Intolerant present less than 10%
	M - 5 - 29%	(Semi-polluted Environment)
	I - 1 -.06%	
SITE # 2	T - 7 - 21%	STREAM CLASSIFICATION OF SITE #2:
	F -12 - 35%	Intolerant present less than 50% but
	M - 9 - 26%	not less than or equal to 10%
	I - 6 - 18%	(Unbalanced Environment).
SITE # 3	T - 4 - 17%	STREAM CLASSIFICATION OF SITE #3:
	F - 8 - 33%	(Unbalanced Environment).
	M - 8 - 33%	
	I - 4 - 17%	
SITE # 4	T - 4 - 14%	STREAM CLASSIFICATION OF SITE #4:
	F -10 - 34%	(Unbalanced Environment).
	M - 9 - 31%	
	I - 6 - 21%	
SITE # 5	T - 5 - 19%	STREAM CLASSIFICATION OF SITE #5:
	F -11 - 41%	(Unbalanced Environment).
	M - 5 - 19%	
	I - 6 - 21%	
SITE # 6	T - 7 - 25%	STREAM CLASSIFICATION OF SITE #6:
	F - 9 33%	(Unbalanced Environment).
	M - 6 21%	
	I - 6 21%	

T - Tolerant
F - Facultative
M - Moderate
I - Intolerant

Table 5

MACROINVERTEBRATE TOLERANCE STATUS

APRIL

	Sampling Sites 1	2	3	4	5	6	Tolerance Range
Bryozoa							
Plumatellidae							
Plumatella punctata							FACULTATIVE
Nematoda							
Nematodes	9*			1			FACULTATIVE
Annelida							
Oligocheata							
Eclipidrilus lacustrus	1						TOLERANT
Lumbriculus variegatus							TOLERANT
Limnodrilus hoffmeisteri	1						TOLERANT
Hirudinea							
Helobdella							FACULTATIVE
Placobdella							TOLERANT
Glossiphonia	5						TOLERANT
Nematomorpha							
Gordius							FACULTATIVE
Paragordius							FACULTATIVE
CRUSTACEA							
Isopoda							
Asellidae							
Lirceus lineatus							MODERATE
Amphipoda							
Talitridae							
Hyalella				7	58	3	INTOLERANT
Decapoda							
Astacidae							
Orconectes				1	1	1	INTOLERANT
INSECTA							
Plecoptera							
Acroneuriidae							
Acroneura					1		INTOLERANT

* number of organisms

Table 6

MACROINVERTEBRATE TOLERANCE STATUS

APRIL	Sampling Sites						Tolerance Range
	1	2	3	4	5	6	
Ephemeroptera							
Baetidae							
Baetis					5*		Intolerant
Isonychia							Intolerant
Ephemeridae							
Hexagenia							Facultative
Caenidae							
Caenis		1	2	2	3	1	Facultative
Heptagenidae							
Heptagenia		12	31	19	16	57	Intolerant
Odonata							
Libellulidae							
Libellula	1	1					Moderate
Coenagrionidae							
Ishnura		18	7	3	15	3	Intolerant
Calopterygidae							
Calopteryx			2	3	3		
Aeshnidae							
Aeshna							
Hemiptera							
Corixidae							
Hespercorixa							Facultative
Veliidae							
Velia							Facultative
Gerridae							
Gerris							Facultative
Trichoptera							
Hydropsychidae							
Hydropsyche						1	Moderate
Cheumatopsyche		25	1	1		1	Moderate
Coleoptera							
Elmidae							
Cylloepus				1	1		Facultative
Dubiraphia					4		Facultative
Stenelmis							Facultative
Dryopidae							
Helichus						2	Facultative

* number of organisms

Table 7

MACROINVERTEBRATE TOLERANCE STATUS

APRIL

	Sampling Sites 1	2	3	4	5	6	Tolerance Range
Hydrophilidae							
Tropisternus							Facultative
Helophorus							Facultative
Enochrus							Facultative
Hydrobius							Facultative
Haliplidae							
Haliplus							Facultative
Peltodytes							Facultative
Dystacidae							
Hydrovatus							Facultative
Diptera							
Chironomidae							
Chironomus	63*	2		1	3	46	Tolerant
Cricotopus		1	1	36	2		Moderate
Stictochironomus		1	1	1	2	8	Moderate
Tribelos				2	1		
Xenochironomus		9					
Glyptotendipes		1	3	4	4	2	Tolerant
Thienemannyia					1		
Cryptochironomus					1		Moderate
Tanytarsus					2		Moderate
Psectrotanypus							
Tanypus							
Cladotanytarsus							
Polypedilum							
Procladius							Facultative
Clinotanypus							Moderate
Heleidae							
Culicoides							Facultative
Anthomyiidae							
Limnophora							Facultative
Culicidae							
Anopheles punctipennis							Tolerant
Stratiomyiidae							
Stratiomyia							Tolerant
Tabanidae							
Haematopota							Facultative
Chrysops							Facultative
Simuliidae							
Simulium				1	2		Moderate

* numbers of organisms

Table 8

MACROINVERTEBRATE TOLERANCE STATUS

APRIL

	Sampling	Sites					Tolerance Range
	1	2	3	4	5	6	
Molluska							
Gastropoda							
Physidae							
Physa	21*	2	3	1	10	3	Tolerant
Lymnaeidae							
Lymnea	2	4					Facultative
Planorbidae							
Gyraulus		3					Facultative
Valvatidae							
Helisoma							Intolerant
Ancylidae							
Ferrissia		2	3	9			Facultative
Pelecypoda							
Sphaeriidae							
Sphaerium	123				6		Moderate
Pisidium		12					Moderate
Lampsilinac							
Leptodea fragilis							

* numbers of organisms

Table 9

MACROINVERTEBRATE TOLERANCE STATUS

MAY

	Sampling Sites 1	2	3	4	5	6	Tolerance Range
Bryozoa							
Plumatellidae							
Plumatella punctata			1*				FACULTATIVE
Nematoda							
Nematodes	17	12			4		FACULTATIVE
Annelida							
Oligocheata							
Eclipidrilus lacustrus		2					TOLERANT
Lumbriculus variegatus							TOLERANT
Limnodrilus hoffmeisteri							TOLERANT
Hirudinea							
Helobdella							FACULTATIVE
Placobdella	1				1		TOLERANT
Glossiphonia	10						TOLERANT
Nematomorpha							
Gordius							FACULTATIVE
Paragordius							FACULTATIVE
CRUSTACEA							
Isopoda							
Asellidae							
Lirceus lineatus						4	MODERATE
Amphipoda							
Talitridae							
Hyalella					3	5	INTOLERANT
Decapoda							
Astacidae							
Orconectes		5				2	INTOLERANT
INSECTA							
Plecoptera							
Acroneuriidae							
Acroneura		2	1	3		1	INTOLERANT

* numbers of organisms

Table 10

MACROINVERTEBRATE TOLERANCE STATUS

May

	Sampling Sites						Tolerance Range
	1	2	3	4	5	6	
Ephemeroptera							
Baetidae							
Baetis		1*		1	3	7	Intolerant
Isonychia							Intolerant
Ephemeridae							
Hexagenia							Facultative
Caenidae							
Caenis			4	3		3	Facultative
Heptagenidae							
Heptagenia		15	29	65	16	41	Intolerant
Odonata							
Libellulidae							
Libellula	1						Moderate
Coenagrionidae							
Ishnura		4	6	8	1	9	Intolerant
Calopterygidae							
Calopteryx				2		8	
Aeshnidae							
Aeshna							
Hemiptera							
Corixidae							
Hespercorixa					1		Facultative
Veliidae							
Velia							Facultative
Gerridae							
Gerris							Facultative
Trichoptera							
Hydropsychidae							
Hydropsyche				1			Moderate
Cheumatopsyche		1		2			Moderate
Coleoptera							
Elmidae							
Cylloepus							Facultative
Dubiraphia						2	Facultative
Stenelmis							Facultative
Dryopidae							
Helichus							Facultative

* numbers of organisms

Table 11

MAY

MACROINVERTEBRATE TOLERANCE STATUS

	Sampling Sites						Tolerance Range
	1	2	3	4	5	6	
Hydrophilidae							
Tropisternus							Facultative
Helophorus							Facultative
Enochrus							Facultative
Hydrobius							Facultative
Haliplidae							
Haliplus							Facultative
Peltodytes							Facultative
Dystacidae							
Hydrovatus							Facultative
Diptera							
Chironomidae							
Chironomus	32*	16	51	6	7	174	Tolerant
Cricotopus	1					2	Moderate
Stictochironomus					1	1	Moderate
Tribelos							
Xenochironomus							
Glyptotendipes							Tolerant
Thienemannyia					1		
Cryptochironomus			1			1	Moderate
Tanytarsus							Moderate
Psectrotanypus							
Tanypus							
Cladotanytarsus		1					
Polypedilum							
Procladius					1		Facultative
Clinotanypus							Moderate
Heleidae							
Culicoides	1						Facultative
Anthomyiidae							
Limnophora							Facultative
Culicidae							
Anopheles punctipennis							Tolerant
Stratiomyiidae							
Stratiomyia							Tolerant
Tabanidae							
Haematopota							Facultative
Chrysops							Facultative
Simuliidae							
Simulium	1	117	14	6			Moderate

* numbers of organisms

Table 12

MACROINVERTEBRATE TOLERANCE STATUS

MAY

	Sampling Sites						Tolerance Range
	1	2	3	4	5	6	
Molluska							
Gastropoda							
Physidae							
Physa	11*		2			8	Tolerant
Lymnaeidae							
Lymnea							Facultative
Planorbidae							
Gyraulus							Facultative
Valvatidae							
Helisoma	5						Intolerant
Ancylidae							
Ferrissia			12	9			Facultative
Pelecypoda							
Sphaeriidae							
Sphaerium	19	9	4				Moderate
Pisidium		13	1				Moderate
Lampsilinae							
Leptodea fragilis							

* numbers of organisms

Table 13

MACROINVERTEBRATE TOLERANCE STATUS

JUNE

	Sampling Sites						Tolerance Range
	1	2	3	4	5	6	
Bryozoa							
Plumatellidae							
<u>Plumatella punctata</u>		1*					FACULTATIVE
Nematoda							
Nematodes	8				5		FACULTATIVE
Annelida							
Oligocheata							
<u>Eclipidrilus lacustrus</u>							TOLERANT
<u>Lumbriculus variegatus</u>							TOLERANT
<u>Limnodrilus hoffmeisteri</u>							TOLERANT
Hirudinea							
<u>Helobdella</u>							FACULTATIVE
<u>Placobdella</u>							TOLERANT
<u>Glossiphonia</u>	11		4				TOLERANT
Nematomorpha							
<u>Gordius</u>							FACULTATIVE
<u>Paragordius</u>							FACULTATIVE
CRUSTACEA							
Isopoda							
Asellidae							
<u>Lirceus lineatus</u>						1	MODERATE
Amphipoda							
Talitridae							
<u>Hyalella</u>		1			5	4	INTOLERANT
Decapoda							
Astacidae							
<u>Orconectes</u>			6	1	1		INTOLERANT
INSECTA							
Plecoptera							
Acroneuriidae							
<u>Acroneura</u>							INTOLERANT

* numbers of organisms

Table 14

MACROINVERTEBRATE TOLERANCE STATUS

JUNE

	Sampling Sites						Tolerance Range
	1	2	3	4	5	6	
Ephemeroptera							
Baetidae							
Baetis		2*				61	Intolerant
Isonychia				2			Intolerant
Ephemeridae							
Hexagenia							Facultative
Caenidae							
Caenis							Facultative
Heptagenidae							
Heptagenia		21	7	29	16	10	Intolerant
Odonata							
Libellulidae							
Libellula							Moderate
Coenagrionidae							
Ishnura		8	6	4	1	1	Intolerant
Calopterygidae							
Calopteryx							
Aeshnidae							
Aeshna							
Hemiptera							
Corixidae							
Hespercorixa							Facultative
Veliidae							
Velia		10					Facultative
Gerridae							
Gerris							Facultative
Trichoptera							
Hydropsychidae							
Hydropsyche				3		5	Moderate
Cheumatopsyche		16		3		4	Moderate
Coleoptera							
Elmidae							
Cylloepus							Facultative
Dubiraphia				6	1	4	Facultative
Stenelmis				3			Facultative
Dryopidae							
Helichus				1			Facultative

* numbers of organisms

Table 15

MACROINVERTEBRATE TOLERANCE STATUS

JUNE

	Sampling Sites 1	2	3	4	5	6	Tolerance Range
Hydrophilidae							
Tropisternus							Facultative
Helophorus							Facultative
Enochrus							Facultative
Hydrobius							Facultative
Haliplidae							
Haliplus							Facultative
Peltodytes							Facultative
Dystacidae							
Hydrovatus							Facultative
Diptera							
Chironomidae							
Chironomus	1*	1	28	2	2	1	Tolerant
Cricotopus							Moderate
Stictochironomus			2	1	3		Moderate
Tribelos				1			
Xenochironomus							
Glyptotendipes							Tolerant
Thienemannyia	2	1					
Cryptochironomus		1					Moderate
Tanytarsus							Moderate
Psectrotanypus							
Tanypus							
Cladotanytarsus							
Polypedilum							
Procladius						1	Facultative
Clinotanypus							Moderate
Heleidae							
Culicoides							Facultative
Anthomyiidae							
Limnophora			1				Facultative
Culicidae							
Anopheles punctipennis							Tolerant
Stratiomyiidae							
Stratiomyia							Tolerant
Tabanidae							
Haematopota							Facultative
Chrysops							Facultative
Simuliidae							
Simulium	79	11					Moderate

* numbers of organisms

Table 16

MACROINVERTEBRATE TOLERANCE STATUS

JUNE

	Sampling Sites 1	2	3	4	5	6	Tolerance Range
Molluska							
Gastropoda							
Physidae							
Physa	24*	2	2			6	Tolerant
Lymnaeidae							
Lymnea							Facultative
Planorbidae							
Gyraulus							Facultative
Valvatidae							
Helisoma	3						Intolerant
Ancylidae							
Ferrissia							Facultative
Pelecypoda							
Sphaeriidae							
Sphaerium	16	3	6				Moderate
Pisidium		11					Moderate
Lampsilinae							
Leptodea fragilis							

* numbers of organisms

Table 17

JULY

MACROINVERTEBRATE TOLERANCE STATUS

	Sampling Sites						Tolerance Range
	1	2	3	4	5	6	
Bryozoa							
Plumatellidae							
Plumatella punctata							FACULTATIVE
Nematoda							
Nematodes	3*		1				FACULTATIVE
Annelida							
Oligocheata							
Eclipidrilus lacustris							TOLERANT
Lumbriculus variegatus							TOLERANT
Limnodrilus hoffmeisteri							TOLERANT
Hirudinea							
Helobdella							FACULTATIVE
Placobdella		6					TOLERANT
Glossiphonia	5	1	4				TOLERANT
Nematomorpha							
Gordius							FACULTATIVE
Paragordius							FACULTATIVE
CRUSTACEA							
Isopoda							
Asellidae							
Lirceus lineatus						4	MODERATE
Amphipoda							
Talitridae							
Hyalella		1			4	1	INTOLERANT
Decapoda							
Astacidae							
Orconectes		2			1		INTOLERANT
INSECTA							
Plecoptera							
Acroneuriidae							
Acroneura				1	1		INTOLERANT

* numbers of organisms

Table 18

MACROINVERTEBRATE TOLERANCE STATUS

JULY

	Sampling Sites 1	2	3	4	5	6	Tolerance Range
Ephemeroptera							
Baetidae							
Baetis		1*					Intolerant
Isonychia							Intolerant
Ephemeridae							
Hexagenia							Facultative
Caenidae							
Caenis		9		5			Facultative
Heptagenidae							
Heptagenia		3	4	5		14	Intolerant
Odonata							
Libellulidae							
Libellula		2					Modérate
Coenagrionidae							
Ishnura		3			1		Intolerant
Calopterygidae							
Calopteryx							
Aeshnidae							
Aeshna							
Hemiptera							
Corixidae							
Hespercorixa							Facultative
Veliidae							
Velia							Facultative
Gerridae							
Gerris							Facultative
Trichoptera							
Hydropsychidae							
Hydropsyche							Moderate
Cheumatopsyche		3					Moderate
Coleoptera							
Elmidae							
Cylloepus							Facultative
Dubiraphia		6		1			Facultative
Stenelmis							Facultative
Dryopidae							
Helichus		1			1		Facultative

* numbers of organisms

Table 19

MACROINVERTEBRATE TOLERANCE STATUS

JULY

	Sampling Sites 1	2	3	4	5	6	Tolerance Range
Hydrophilidae							
Tropisternus	1*						Facultative
Helophorus							Facultative
Enochrus							Facultative
Hydrobius							Facultative
Haliplidae							
Haliplus							Facultative
Peltodytes							Facultative
Dystacidae							
Hydrovatus							Facultative
Diptera							
Chironomidae							
Chironomus	7			1			Tolerant
Cricotopus							Moderate
Stictochironomus	23			1	13		Moderate
Tribelos							
Xenochironomus							
Glyptotendipes							Tolerant
Thienemannyia			1				
Cryptochironomus	1		1				Moderate
Tanytarsus							Moderate
Psectrotanypus	3						
Tanypus	2						
Cladotanytarsus							
Polypedilum							
Procladius							Facultative
Clinotanypus							Moderate
Heleidae							
Culicoides							Facultative
Anthomyiidae							
Limnophora							Facultative
Culicidae							
Anopheles punctipennis				2			Tolerant
Stratiomyiidae							
Stratiomyia							Tolerant
Tabanidae							
Haematopota							Facultative
Chrysops							Facultative
Simuliidae							
Simulium							Moderate

* numbers of organisms

Table 20

MACROINVERTEBRATE TOLERANCE STATUS

JULY

	Sampling Sites						Tolerance Range
	1	2	3	4	5	6	
Molluska							
Gastropoda							
Physidae							
Physa	21*	22	2	1	11	5	Tolerant
Lymnaeidae							
Lymnea		1					Facultative
Planorbidae							
Gyraulus							Facultative
Valvatidae							
Helisoma	4						Intolerant
Ancylidae							
Ferrissia			2				Facultative
Pelecypoda							
Sphaeriidae							
Sphaerium	4		12	8			Moderate
Pisidium				13			Moderate
Lampsilinae							
Leptodea fragilis							

* numbers of organisms

Table 21

MACROINVERTEBRATE TOLERANCE STATUS

OCTOBER

	Sampling Sites 1	2	3	4	5	6	Tolerance Range
Bryozoa							
Plumatellidae							
Plumatella punctata							FACULTATIVE
Nematoda							
Nematodes	2*		3			12	FACULTATIVE
Annelida							
Oligocheata							
Eclipidrilus lacustrus							TOLERANT
Lumbriculus variegatus							TOLERANT
Limnodrilus hoffmeisteri							TOLERANT
Hirudinea							
Helobdella							FACULTATIVE
Placobdella		5				3	TOLERANT
Glossiphonia	10		1		1	2	TOLERANT
Nematomorpha							
Gordius						1	FACULTATIVE
Paragordius							FACULTATIVE
CRUSTACEA							
Isopoda							
Asellidae							
Lirceus lineatus						11	MODERATE
Amphipoda							
Talitridae							
Hyalella		6		2	7	10	INTOLERANT
Decapoda							
Astacidae							
Orconectes				1	1	1	INTOLERANT
INSECTA							
Plecoptera							
Acroneuriidae							
Acroneura							INTOLERANT

* numbers of organisms

Table 22

OCTOBER

MACROINVERTEBRATE TOLERANCE STATUS

	Sampling Sites						Tolerance Range
	1	2	3	4	5	6	
Ephemeroptera							
Baetidae							
Baetis		1*					Intolerant
Isonychia							Intolerant
Ephemeridae							
Hexagenia							Facultative
Caenidae							
Caenis				4	1		Facultative
Heptagenidae							
Heptagenia						1	Intolerant
Odonata							
Libellulidae							
Libellula		13					Moderate
Coenagrionidae							
Ishnura		8		3	11	9	Intolerant
Calopterygidae							
Calopteryx							
Aeshnidae							
Aeshna						1	
Hemiptera							
Corixidae							
Hespercorixa		9	1	3	1		Facultative
Veliidae							
Velia							Facultative
Gerridae							
Gerris					1		Facultative
Trichoptera							
Hydropsychidae							
Hydropsyche							Moderate
Cheumatopsyche							Moderate
Coleoptera							
Elmidae							
Cylloepus							Facultative
Dubiraphia					2	2	Facultative
Stenelmis				1			Facultative
Dryopidae							
Helichus							Facultative

* numbers of organisms

Table 23

OCTOBER

MACROINVERTEBRATE TOLERANCE STATUS

	Sampling Sites 1	2	3	4	5	6	Tolerance Range
Hydrophilidae							
Tropisternus				1*			Facultative
Helophorus							Facultative
Enochrus							Facultative
Hydrobius							Facultative
Haliplidae							
Haliplus							Facultative
Peltodytes							Facultative
Dystacidae							
Hydrovatus							Facultative
Diptera							
Chironomidae							
Chironomus				1	1	7	Tolerant
Cricotopus							Moderate
Stictochironomus							Moderate
Tribelos							
Xenochironomus							
Glyptotendipes							Tolerant
Thienemannyia					2		
Cryptochironomus						1	Moderate
Tanytarsus							Moderate
Psectrotanypus							
Tanypus							
Cladotanytarsus		9			6		
Polypedilum							
Procladius				1			Facultative
Clinotanypus		2					Moderate
Heleidae							
Culicoides	1						Facultative
Anthomyiidae							
Limnophora							Facultative
Culicidae							
Anopheles punctipennis							Tolerant
Stratiomyiidae							
Stratiomyia						1	Tolerant
Tabanidae							
Haematopota			1				Facultative
Chrysops						1	Facultative
Simuliidae							
Simulium							Moderate

* numbers of organism

Table 24

MACROINVERTEBRATE TOLERANCE STATUS

OCTOBER

	Sampling Sites						Tolerance Range
	1	2	3	4	5	6	
Molluska							
Gastropoda							
Physidae							
Physa	2*	2	1	1		3	Tolerant
Lymnaeidae							
Lymnea		1				11	Facultative
Planorbidae							
Gyraulus							Facultative
Valvatidae							
Helisoma	9						Intolerant
Ancylidae							
Ferrissia							Facultative
Pelecypoda							
Sphaeriidae							
Sphaerium	1	2	6		3		Moderate
Pisidium		3		1			Moderate
Lampsilinae							
Leptodea fragilis		1					

* numbers of organisms

Table 25

MACROINVERTEBRATE TOLERANCE STATUS

NOVEMBER

	Sampling Sites						Tolerance Range
	1	2	3	4	5	6	
Bryozoa							
Plumatellidae							
Plumatella punctata							FACULTATIVE
Nematoda							
Nematodes		8*	13	3			FACULTATIVE
Annelida							
Oligocheata							
Eclipidrilus lacustrus	1		4			2	TOLERANT
Lumbriculus variegatus					1		TOLERANT
Limnodrilus hoffmeisteri	3						TOLERANT
Hirudinea							
Helobdella		3					FACULTATIVE
Placobdella							TOLERANT
Glossiphonia	6				1		TOLERANT
Nematomorpha							
Gordius							FACULTATIVE
Paragordius							FACULTATIVE
CRUSTACEA							
Isopoda							
Asellidae							
Lirceus lineatus						5	MODERATE
Amphipoda							
Talitridae							
Hyalella		8			2	4	INTOLERANT
Decapoda							
Astacidae							
Orconectes						2	INTOLERANT
INSECTA							
Plecoptera							
Acroneuriidae							
Acroneura							INTOLERANT

* numbers of organisms

Table 26

MACROINVERTEBRATE TOLERANCE STATUS

NOVEMBER

	Sampling Sites						Tolerance Range
	1	2	3	4	5	6	
Ephemeroptera							
Baetidae							
Baetis							Intolerant
Isonychia							Intolerant
Ephemeridae							
Hexagenia					1*		Facultative
Caenidae							
Caenis				4	1		Facultative
Heptagenidae							
Heptagenia							Intolerant
Odonata							
Libellulidae							
Libellula							Moderate
Coenagrionidae							
Ishnura		10		2	1	24	Intolerant
Calopterygidae							
Calopteryx							
Aeshnidae							
Aeshna							
Hemiptera							
Corixidae							
Hespercorixa		7		2	2	2	Facultative
Veliidae							
Velia							Facultative
Gerridae							
Gerris							Facultative
Trichoptera							
Hydropsychidae							
Hydropsyche						1	Moderate
Cheumatopsyche						2	Moderate
Coleoptera							
Elmidae							
Cylloepus							Facultative
Dubiraphia				1	3		Facultative
Stenelmis				2			Facultative
Dryopidae							
Helichus				1	1	1	Facultative

* numbers of organisms

Table 27

MACROINVERTEBRATE TOLERANCE STATUS

NOVEMBER

	Sampling Sites 1	2	3	4	5	6	Tolerance Range
Hydrophilidae							
Tropisternus							Facultative
Helophorus							Facultative
Enochrus				1*			Facultative
Hydrobius							Facultative
Haliplidae							
Haliplus							Facultative
Peltodytes							Facultative
Dystacidae							
Hydrovatus							Facultative
Diptera							
Chironomidae							
Chironomus				1	7	12	Tolerant
Cricotopus							Moderate
Stictochironomus					1		Moderate
Tribelos							
Xenochironomus							
Glyptotendipes							Tolerant
Thienemannyia					4	2	
Cryptochironomus							Moderate
Tanytarsus							Moderate
Psectrotanypus						1	
Tanypus						1	
Cladotanytarsus		1					
Polypedilum					1		
Procladius							Facultative
Clinotanypus		1					Moderate
Heleidae							
Culicoides							Facultative
Anthomyiidae							
Limnophora							Facultative
Culicidae							
Anopheles punctipennis							Tolerant
Stratiomyiidae							
Stratiomyia	1						Tolerant
Tabanidae							
Haematopota							Facultative
Chrysops							Facultative
Simuliidae							
Simulium				1			Moderate

* numbers of organisms

Table 28

MACROINVERTEBRATE TOLERANCE STATUS

NOVEMBER

	Sampling Sites						Tolerance Range
	1	2	3	4	5	6	
Molluska							
Gastropoda							
Physidae							
Physa	3*	2	3	3	1	3	Tolerant
Lymnaeidae							
Lymnea				2			Facultative
Planorbidae							
Gyraulus							Facultative
Valvatidae							
Helisoma							Intolerant
Ancylidae							
Ferrissia					1	5	Facultative
Pelecypoda							
Sphaeriidae							
Sphaerium		3	1				Moderate
Pisidium							Moderate
Lampsilinae							
Leptodea fragilis							

* numbers of organisms